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ABSTRACT

Twenty-four teachers, from a school system not using the new elementary science programs, taught representative new units to 544 students, with variations in their inservice training and the amount of classroom science equipment provided. Classrooms at three grade levels (1, 3, and 6) were used twice under opposing conditions. For each unit, the teachers selected for training received a teacher's guide and specific training for the unit. The teachers not selected for training received only a teacher's guide. Some classrooms received sufficient laboratory instructional aids to allow students to work in small groups of two to four students; others received minimal equipment so that their lessons included demonstrations rather than maximal interaction of children with materials. Pupils were given individual oral tests to assess subject matter achievement. Additional equipment resulted in significantly greater achievement only at the first grade level, but all pupils expressed a preference for additional aids. Specific teacher training for the unit did not produce significant differences in pupil achievement. Additional data regarding the effects of sex, I.Q., and family occupation on pupil achievement and pupil preferences are reported. (EB)

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FINAL REPORT

Project No. 8-B-020

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A Study of the Effects on Student Achievement in Elementary Science Programs Resulting from Teacher In-Service Training and Additional Instructional Aids.

George F. Smith

Cornell University
Ithaca, New York
June, 1969

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No matter how theoretically sound any educational research project may be it will all be for nothing without the manpower to carry it out. In this project a dozen women donated hundreds of hours of their time to administer roughly one thousand individual-oral examinations. They were Mrs. Norman Aubrey, Mrs. Howard Bilz, Mrs. William Cavanaugh, Mrs. Edward Clancy, Mrs. William Durfee, Mrs. John Durso, Mrs. Charles Hamilton, Mrs. Dale Johnston, Mrs. Warren Maxfield, Mrs. Bruce Morin, Mrs. Linus Pauling, Mrs. George Smith, and Mrs. Freeman Young. The testing organization was highly efficient and operated autonomously under the leadership of Mrs. Smith.

Finally recognition is given to the twenty-four South Hadley elementary school teachers who taught the experimental units, their principals who gave us the freedom necessary to conduct the research, and their superintendent and school committee who gave us their full support.

This research represents the joint efforts of some sixty individuals from various academic levels and walks of life. It really was a co-operative effort in which the author acted as a manager and co-ordinator. As is usual in these enterprises the author must accept full responsibility for all bad advice which was followed and all good advice which was rejected.

CHAPTER I

SUMMARY

Twenty-four elementary teachers, from a school system not using the new elementary science programs, taught representative units to 544 students with restrictions on their in-service training and amount of classroom science equipment. The basic design was a one-half replication of a 2^4 factorial experiment. Both halves of the one-half replication were provided at each of three grade levels (1, 3, and 6) by using each classroom twice under opposing conditions. Standard procedures for a randomized-incomplete block design were followed using analysis of variance (factorial design).

The in-service education of teachers selected for training consisted of a single one-hour session after school in which teachers were given a description of each activity in the unit followed by first hand experience, under supervision, doing the same things with the same materials that their pupils would do in the unit. The training session concluded with a group discussion of the activities including background scientific information, anticipated classroom problems, and an emphasis of the objectives of the unit. Teachers' guides similar to those provided with certain of the current NSF supported elementary science programs were given to all teachers.

Some classrooms received minimal amounts of laboratory, instructional aids so that their lessons were essentially demonstrative, supplemented by various exercises and activities in which the children could take turns manipulating the laboratory materials. Other classrooms received additional laboratory, instructional aids so that the children working simultaneously in small groups of 2 - 4 students had ample opportunity to interact with the materials and other students. In general a classroom supplied with minimal amounts of laboratory, instructional aids received about the same total amount of material that was provided to a small group of four students in the classroom supplied with additional amounts of aids. Lessons for the classrooms having minimal instructional aids were written specifically to maximize the amount of direct experience that the children would have even with the limited materials.

Standard question formats for individual oral testing of pupils were established for each unit. Generally a pair of evaluators was assigned to do all of the testing on any one particular unit.

Having additional instructional aids resulted in significantly higher pupil achievement on subject matter tests only at the first grade level but at the third and sixth grade levels pupils preferred units having additional instructional aids over those with minimal aids. Specific teacher training did not produce significantly different pupil achievement and teachers did not think that in-service training was necessary even though many expressed the feeling that they would prefer to have it.

As practical guidelines for school systems it is recommended that sufficient additional instructional aids be provided for the first few elementary grades so that students can interact with materials and other students in small groups. When the materials are not costly, additional amounts of instructional aids should be purchased to satisfy student preferences.

Teachers' guides similar to those provided with the current NSF supported elementary science programs are effective with elementary school teachers who do not have special in-service training. The implementation problem for the new elementary science programs seems to be basically one of overcoming teacher and administrative inertia and not one of teacher training.

CHAPTER II

INTRODUCTION

The purpose of this investigation is to generate some basic information for local school systems to consider when implementing changes in their elementary science programs. The information generated concerns the effects of teacher in-service training and additional instructional aids on the following:

1. Pupil achievement on subject matter tests.
2. Pupil preference on equipment amounts.
3. Teacher time involvement (preparation, teaching, clean-up).
4. Teacher opinions on the necessity of in-service training.
5. Teacher reactions to materials and methods.
6. Teacher opinions on the necessity for student text materials.
7. Number of repetitions of demonstrations.

The amount of elementary science equipment and materials was varied from what was necessary to have many small groups of children working simultaneously to what appeared suitable for single group instruction. Teachers were either trained or not trained. The results are applicable to many science programs for elementary grades.

Problem

Each year a sizable number of communities in the United States evaluate their programs and try to improve them in accordance with recommendations of a faculty committee. In New York state alone a "total of 2,657 new instructional programs" were begun by "486 of the public school systems" between 1953 and 1960. (Brickell, 1961)

In the years immediately ahead much attention undoubtedly will be focused on elementary science programs since "interest in improving course content and methods of teaching science at all levels of the school system is at an all time high." (Piltz, 1964). The committees that start work on elementary science programs in the next few years will find that much of the materials currently produced are unfamiliar to the teachers and involve a great deal of small group laboratory instruction. Since the materials are unfamiliar, faculty committees may be asked to make recommendations on the nature and amount of in-service training necessary to institute the improvements. Henry (1964) believes that "Some form of in-service program is necessary." Although teachers' guides are produced to accompany much of the new materials, there is a question as to the effectiveness of these guides for the elementary teacher who does not have special in-service training. Many elementary teachers who look at the new and strange materials must wonder if they are designed for use by exceptional teachers. The unfamiliar may look more difficult than it really is.

A faculty committee may also experience controversy on the question of small group laboratory instruction vs. classroom demonstrations. Some committee members may point out the expense involved in purchasing several hundred dollars' worth of laboratory equipment for each elementary school classroom as compared to the lesser expense of purchasing demonstration quantities. For example, the price of an individual AAAS first grade classroom unit (30 pupils) is listed at $257.00 by the Xerox Education Division.

Some members may point out the benefits of first-hand experience in small laboratory groups such as opportunities for group interaction, manipulation of materials, and independent investigation. Others will cite the possibility of classroom confusion, inefficient learning, and bad pupil habits that may result. Obviously the faculty committee will be forced to rely on opinion rather than on objective evidence to make its decisions on this matter since little data seem to have been collected. Even noted writers such as Piaget (Ripple and Rockcastle, 1964) and Ausubel (1963) disagree apparently on the relative merits of individual manipulation and discussion-demonstrations for elementary school children.

Evidence, not opinion, is needed to show how effective teachers' guides are for the training of elementary teachers. Evidence, not opinion, is also needed to show whether small group laboratory type instruction using additional instructional aids is more effective than discussions coupled with demonstrations and exercises that use only demonstrable quantities of science aids. Funds for new elementary science programs will be difficult to obtain without supporting evidence since some school committee members feel that "to date, no substantial evidence has been produced to show that students do any better on the new programs than the old." (Calandra, 1964) Some feel that they have "become victims of a hard sell blitzkreig." (Ibid.)

In addition, according to Newport (1965), "there are indications that the majority of school systems are not now in a position to secure the equipment called for in the new programs." The odds for adequate financial support of the science programs are further diminished by a traditional expectation that elementary teachers "be responsible for obtaining the equipment and materials to be used in teaching science." (Ibid.) A final complicating factor is that elementary science occupies such a small part of the curriculum in the lower grades. Blackwood (1964) says that in the lower grades "only a small percent of schools" teach science "as much as 200 minutes a week (an average of 40 minutes a day)." It seems inevitable that school committees and administrators will attempt to reduce the cost of these programs to their communities by eliminating in-service training and reducing amounts of recommended equipment.

CHAPTER III

RELATED LITERATURE

In a speech at the State College at Worcester, Massachusetts, in November, 1968, Dr. Maurice Belanger, Harvard Graduate School of Education stated that much of the current curriculum controversy in science and in the areas of English, mathematics, social studies, foreign languages, guidance, and educational administration is really based on controversies in the philosophy and psychology of learning. Taking science as an example of the controversy, Belanger pointed out that in science there is a structure tree of events in nature, concepts about these events, and generalizations about these concepts. The structure of science and any of its disciplines makes it possible for us to explain events, predict future events, and control our environment. Psychologists will agree that children have less trouble learning material which has a structure. They will also agree that children can usually be brought into the study of any structured discipline at some appropriate level. In elementary school science this means that the teacher must rely heavily on material objects. According to Belanger the differences between the new elementary science curricula are really based on what is going to be done with these physical materials.

Each of the major curriculum projects in elementary science has a different emphasis. The American Association for the Advancement of Science (Livermore, 1964) chose to emphasize the processes of science. Their program, "Science-A Process Approach," is primarily oriented toward developing in children certain skills and behaviors that are considered appropriate in science. The materials are used in the AAAS program in such a way as to influence the behavior of students towards attainment of the appropriate skills. In this particular program there is less concern for the structure of science or the learning of scientific facts in the various subject areas. The AAAS program, however, is highly structured towards the attainment of the specified skills and behaviors. All lessons have behavioral goals, and competency measures, both individual and group, to measure the attainment of these goals. Teachers' guides and most necessary classroom materials are included with the program.

The Elementary Science Study project (Nichols, 1964) emphasizes investigations with familiar and readily available objects. Its general philosophy seems to consider learning as a process of interaction between the mind of a person and his surroundings. The ESS group seems to be using objects in such a way as to stimulate interaction (manipulation, thought, concern, interest) between children and the world around them with hope that the basic mental patterns (intelligence, attitudes, interests) can be changed. They have "devoted much time to finding equipment and living things that can lead to rich and manageable experimentation by children but that are as cheap and familiar as possible." (Ibid.) Without attempting to minimize the teacher retraining problem, ESS has tried to work around the problem by keeping in mind while writing teachers' guides the fact that most teachers who will be using their guides know "a great deal about many other subject areas but very little about the particular one at hand." (Ibid.) The most capable trial teachers, regardless of previous training, have been those that "encourage the enthusiasm and eagerness of their pupils and become eager and enthusiastic themselves." (Ibid.) Experience in being personally involved in a search for knowledge is considered to be more important than knowledge of the facts of science. The structure of science is not emphasized in ESS units and the units are not interconnected.

The School Science Curriculum Project is searching for effective methods and the best content for current and future needs. (Salinger, 1966) The SSCP group directed its early development stages around the question "What should an adult know about science?" The Project then worked backwards to find out what could be inserted where in the curriculum. Children are used in the original writing of lessons to moderate the work by providing the key to guide writers in determining how much, and at approximately what age level, certain topics can be inserted to begin building competence in a particular area. In the trial teaching the materials have been structured to let a child "deal with natural phenomena that can be observed, measured, questioned, and classified by his own senses." (Ibid.) Salinger mentions that the teachers's own eagerness closely correlates with the succesful use of SSCP materials. The "intention is to foster lively classroom discussion, intelligently led, in which the teacher becomes a moderator and listens, and the child acts as the chief participant." (Ibid.) Effective communication of details of the structures of scientific disciplines is the primary interest of SSCP.

Finally the Science Curriculum Improvement Study is oriented toward topics that deal with fundamental aspects of nature (Karplus, 1962). The SCIS group operates on the premise that teaching the structure of science is the most important thing to do. They note that there are some very high order concepts that can be applied to many scientific situations. The SCIS group is building its curriculum in such a way as to teach these high order concepts. It is felt that the elementary science program should help children make the transition between two levels of mental activity. "The initial level is observational, manipulative, descriptive, concerned with objects and skills; the final level is analytical, abstract, and concerned with relations and understanding." (Ibid.)

Belanger stated in the Worcester speech that the basic differences in the philosophy and psychology of learning have not and probably cannot be resolved. They are differences which have existed for centuries. Each teacher actually has his own views on the basic issues. He suggested that teachers and school systems pick out the program that most appeals to them and move ahead with it. Doing something is better than debating irresolvable philosophies and doing nothing.

While each of the current elementary science curriculum projects differs in its primary objectives, they do agree that physical materials must play an important role in the elementary science program. Many lessons in the developed teachers' guides recommend having sufficient quantities of physical materials in the classroom to make it possible for children to work in very small groups (two to four). The most obvious advantage of having small group work is that students have more first-hand experience interacting with materials and with each other than when larger groupings are used. A question arises as to whether or not these lessons could just have well been written using drastically reduced amounts of physical material, demonstration quantities, in the classroom without appreciable loss of effectiveness. How valuable is this additional interaction experience? Is it worth the extra cost in time and money?

Ausubel (1961) claims that

> In the absence of prior discovery and nonverbal experience, children approximately below the age of twelve tend to find directly presented verbal constructs of any complexity unrelatable to existing cognitive structure, and hence devoid of potential meaning.

He says that children generally require direct experience with the actual diverse instances underlying concepts and generalizations as well as proximate, nonverbal contact with the objects or situations involved. He feels that concepts and verbal materials directly presented are too distantly removed from empirical experience to be relatable to the existing cognitive structure of elementary school children. This doesn't mean that actual discovery is required before meaningfulness can occur. So long as direct, nonverbal contact with the data is a central part of the learning process, verbal concepts and generalizations can be meaningful to children even though they are presented rather than discovered. However, Ausubel also feels that in the elementary school years, it is normally preferable to encourage children to complete the final step of discovering inferences from data independently rather than by direct presentation of the inferences.

In a later work (1963) he says that the teaching of elementary school science must be directed toward a semiabstract or intuitive type of learning since the children depend on concrete-empirical experience for meaningful understanding of abstract propositions.

> This does not mean, however, that all or even most teaching must necessarily be conducted on an inductive, problem-solving (discovery), and nonverbal basis. The only essential condition for learning relational concepts during this period is the availability of first-hand, nonrepresentational, and empirical experience. Didactic verbal exposition can easily be combined with such concrete-empirical props in the form of demonstrations and exercises, and usually suffices for the presentation of most subject matter that is neither excessively complex nor unfamiliar. In some instances it might be desirable to enhance verbal exposition with a semi-autonomous type of problem-solving in which discovery is accelerated by the use of prompts, hints, and Socratic questioning.

It can be seen that Ausubel recommends that real materials be available in the elementary school classroom when science is being taught. He is not specific as to how much material should be there but apparently didactic verbal exposition combined with demonstrations and exercises is considered to be sufficient in many cases. One interpretation of these remarks that will be taken by economy minded school committees and administrators is that minimal amounts (normally demonstration quantities) of science materials should be supplied unless there is evidence that a laboratory approach using additional amounts of materials will be beneficial. They will argue that exercises can be done as demonstrations by small groups in front of a class or done individually by children in a science corner whenever individuals are free from other obligations.

On the other hand, Piaget (Ripple and Rockcastle, 1964) would recommend that sufficient quantities of equipment for individual manipulation in small groups are necessary.

> Experience is always necessary for intellectual development.... But I fear that we may fall into the illusion that being submitted to an experience (a demonstration) is sufficient for a subject to disengage the structure involved. But more than

> this is required. The subject must be active, must transform things, and find the structure of his own actions on the objects.

He means the term "active" in two senses, namely, manipulation and social collaboration.

Piaget describes three major stages of intellectual development (sensory-motor, concrete operations, and formal operations). He uses the term "concrete" to indicate that a child can mentally perform actions which he has actually done at some previous time. During the first few elementary school years children are making the transition into the concrete operational stage. During the upper elementary grades they begin the transfer into the formal operations stage though some children never do make the transition. A child who is at the formal operations level is able to deal with abstractions apart from actuality. According to Piaget the factors responsible for the transition from one level of thinking to another are maturation, experience with the physical world, social experience, and self-regulation. The latter, he says, means that children should be allowed a maximum of activity of their own, directed by means of materials which allow their activities to be cognitively useful.

Ausubel and Piaget, while agreeing on the importance of having concrete materials in the classroom, do not agree that there should be enough additional quantities of materials to allow for individual manipulation and social interactions in small groups. The question exists then as to the effects of additional instructional aids on student achievement in elementary science programs. Instructional material amounts are controlled by administrators and school committees who are under obligation to the taxpayers not to waste funds. It is assumed that teachers will do the best job that they can with the materials and time provided. If Piaget's opinion is correct then a capital investment of several hundred dollars per elementary classroon will produce a significant improvement in student science achievement while drastically smaller investments will result in wasted funds. However, if Ausubel's opinion is correct then only minimal amounts of instructional aids are necessary and the investment of hundreds of dollars per elementary classroom could be put to better use.

The work of Suchman (1962) on scientific inquiry training in the elementary schools may be of interest to the reader even though the teaching technique is rather unorthodox and probably not acceptable to most teachers and administrators. Suchman found that conceptual growth was not hindered when students saw only a movie film of a demonstration and were allowed to ask their teacher questions about the demonstration that were answerable only by "yes" or "no." The control group in this experiment was shown the same films as the inquiry group but the teachers deleted the inquiry technique and used the usual expository and didactic methods including additional demonstrations, reading assignments, lecture-type expositions, and concrete laboratory experiences. This work is an indication that apparently there may be a wide latitude of equally promising procedures for teaching elementary school science. Apparently no one best method exists.

The problem of teacher preparation for the new elementary science curricula has been a matter of concern expressed by each of the new curriculum projects. At the time of the classroom phase of this research none of the curriculum projects had a tested teacher-education program for their materials although most were attempting to prepare such a program. At the time of this writing both SCIS and AAAS have trial materials available for fairly extensive in-service training programs. ESS has some implementation formats available that have been used successfully by some communities. To date no solid information is available on the effectiveness of these implementation schemes but it should be available within the next year. The teacher training and implementation problem is just beginning.

As a final word of caution it should be mentioned that many experiments have attempted to compare one teaching method with another. The traditional finding in these experiments is "no significant difference." Pella (1961) suggests that the traditional "no significant difference" result may be due to the fact that, "A method or tool in the hands of the unskilled may fail because of the lack of effective administration or execution." It follows, therefore, that in order to make a valid appraisal of the new elementary science curricula, teachers must be proficient in using the methods and materials undergoing evaluation. In a practical sense communities have very little that they can do about this teacher proficiency problem. Either the teachers are already proficient or else they must be able to become proficient by self education and/or a small in-service training program. If really extensive training is necessary to make teachers proficient in the new curricula then the prognosis for implementation of these programs is bad.

CHAPTER IV

DESCRIPTION OF ACTIVITIES

The effects of teacher in-service training and additional elementary science instructional aids are being studied in a community that has not been exposed to an elementary school science curriculum change in twenty years. Twenty-four classrooms in the community of South Hadley, Massachusetts, are participating in this study. The community has no science texts for grades 1 - 3 and teachers in these grades spend 0 - 30 minutes per week on science. For grades 4 - 6 the science texts were published about twenty years ago and the teachers spend about 90 minutes per week on science. During the last few fiscal years the elementary science budget in the school system has been almost zero.

During the 1968-69 school year the South Hadley faculty will undertake a study to enable it to make recommendations to the school committee for improving the elementary science curriculum. In preparation for this curriculum study the school committee granted sabbatical leave to the author, chairman of the local high school science department, with the mandate to prepare himself to become chairman of the science curriculum revision committee. During his sabbatical year at Cornell University the author concluded that several types of activities would have to be conducted in the community prior to the formation of the curriculum committee. Large numbers of teachers had to have some direct experience with material-oriented, non-textbook types of elementary school science lessons such as those being currently developed with National Science Foundation funds. Unless the teachers had first-hand experience it was thought that they would not be able to evaluate properly the new teaching philosophies and materials.

In addition to providing the teachers with direct experience there were practical problems that would have to be faced in case the curriculum committee should happen to adopt one of the new, NSF supported, elementary science programs. Within hundreds of miles there were no colleges offering courses that teachers could attend to become proficient at working with the new materials. This means that the local school system would probably have to arrange its own in-service training for the implementation of new elementary science curricula. Since public schools are oriented towards the education of children and not towards the professional training of their staff, the school system would be treading on unfamiliar ground if it undertook the job of professional retraining of teachers that has traditionally been the responsibility of teacher-training institutions. The South Hadley staff needed some direct experience in the problems of operating a local in-service training program and needed to determine for itself how much of an in-service training problem it was going to face in case a decision was made in favor of a new, material oriented science program.

Another practical problem that needed study was that of teacher reaction to the large amount of physical material that would be present in the classroom for new type lessons. It was anticipated that teachers might be apprehensive about their abilities to control the children under learning situations that required large amounts of stimulating materials to be used individually by students. The teachers might prefer to have fewer materials and conduct demonstrations or have a science corner in the room just to avoid potential discipline problems. Also considering the fact that very little funds are budgeted for elementary school science it was anticipated that obvious advantages and benefits to the children would have to be found before the local school committee could reasonably be expected to provide funds for more than a bare minimum of elementary science materials.

After the situation had been explained to the superintendent of the South Hadley public schools a decision was reached to conduct this research project during the 1967-68 school year to give the community and teachers some controlled experience with the anticipated problems of implementing a material-oriented, non-textbook, elementary science program. The superintendent of schools and the school committee cooperated in this research by making available as many classrooms as were necessary so long as the teachers were not required to cooperate by administrative decree. Since the project had the backing of the school committee, there was no problem at all in getting the cooperation of the twenty-four elementary teachers that were needed.

To meet the objectives of this research it was necessary to use as many teachers as possible without creating a situation that could not be kept under control. A research design that required as little non-classroom time as possible on the part of cooperating teachers had to be used. Cost had to be kept minimal by developing trial units that used materials presently owned by the school system or that could be purchased for less than a total of $100. The school system agreed to cover the cost of the laboratory materials that were needed. The actual cost of classroom materials ran closer to $50 than the expected $100.

An experimental design (Figure 1) tailored to the community situation was developed at Cornell University during the summer of 1967 with the cooperation and advice of faculty members from the Department of Education. The design is a one-half replication of a 2^4 factorial experiment. Both halves of the one-half

Experimental Design
Figure 1

Teacher	Grade	First Unit	Training	Instructional Aids Amount	Second Unit	Training	Instructional Aids Amount
1	1	A	yes	large	B	no	small
2	1	B	yes	large	A	no	small
3	1	A	no	large	B	yes	small
4	1	B	no	large	A	yes	small
5	1	A	yes	small	B	no	large
6	1	B	yes	small	A	no	large
7	1	A	no	small	B	yes	large
8	1	B	no	small	A	yes	large
9	3	C	yes	large	D	no	small
10	3	D	yes	large	C	no	small
11	3	C	no	large	D	yes	small
12	3	D	no	large	C	yes	small
13	3	C	yes	small	D	no	large
14	3	D	yes	small	C	no	large
15	3	C	no	small	D	yes	large
16	3	D	no	small	C	yes	large
17	6	E	yes	large	F	no	small
18	6	F	yes	large	E	no	small
19	6	E	no	large	F	yes	small
20	6	F	no	large	E	yes	small
21	6	E	yes	small	F	no	large
22	6	F	yes	small	E	no	large
23	6	E	no	small	F	yes	large
24	6	F	no	small	E	yes	large

Units were adapted from current materials designed for appropriate grade level. (Appendix B)

Teachers are either trained or not trained.

Instructional aids were furnished in either large (additional for full lab instruction) or small (minimal, demonstration quantities) amount to the classes.

replication are provided at each of three levels by using each classroom twice under opposing conditions. The design is treated statistically as a complete 2^4 factorial experiment with the knowledge that interactions are confounded with classroom diferences. The term, "confounded," is a technical term meaning that the effects of several variables are confused and cannot be distinguished clearly. In this case any interactions that are present are confused with classroom differences so that the effects of interactions and classroom differences cannot be logically separated. The effect of this method of handling the data is to counterbalance each teacher and class against itself.

The independent variables in this study are (a) teacher in-service training and (b) amount of laboratory, instructional aids. For each unit the teachers selected for training received a teachers' guide to the unit (Appendix B) and specific training in the teaching methods that they would use and the subject matter involved. The teachers not selected for training received only a teachers' guide. The in-service education of teachers selected for training consisted of a single one hour session after school (3:30-4:30) in which they were given:

1. A general introduction to the purpose of the research.
2. Specific instructions on the collection and recording of data.
3. A description of each activity in the unit followed by first hand experience, under supervision, doing the same things with the same materials that their pupils would do in the unit.
4. A group discussion of the activities including background scientific information, anticipated classroom problems, and an emphasis on the objectives of the unit.

Some classrooms received only minimal amounts of laboratory, instructional aids so that their lessons were normally of the demonstration variety supplemented by various exercises and activities in which the children could take turns manipulating the laboratory materials. Other classrooms received additional laboratory, instructional aids so that the children could work simultaneously in small groups of 2 - 4 students and have ample opportunity to interact with the materials and other students. As a rough generalization a classroom supplied with minimal amounts of laboratory instructional aids received about the same total amount of material that was provided to a small group of four students in the classroom supplied with additional amounts of aids. For each type of classroom there was a different version of the teachers' guide. Specific material listings for each type unit are given in the teachers' guides (Appendix B) for comparison. Lessons for the classrooms having minimal instructional aids were specifically written to maximize the amount of direct experience that the children would have even with the limited materials.

To minimize any possible teacher antagonism all materials that were needed for this research in any classroom were provided in a kit form. All of the training of teachers for a given grade level was done in one week. Over the following few weeks the classrooms of that grade level conducted their lessons on a staggered basis so that the same kits could be used many times over after replenishment. The same pattern was repeated for each of the three grade levels that were used.

The dependent variables in the study are:

1. Pupil achievement on subject matter tests.
2. Pupil preference on equipment amounts.
3. Teacher time involvement (preparation, teaching, clean-up).
4. Teacher opinions on the necessity of in-service training.
5. Teacher reactions to materials and methods.
6. Teacher opinions on the necessity for student text materials.
7. Number of repetitions of demonstrations.

Data on items 1 and 2 were obtained by independent evaluators questioning individual students. Data on items 3 - 7 were obtained through questionnaires administered to the teachers.

Standard question formats for individual oral testing of pupils were established for each unit (Appendix C). The testing was done by about a dozen women of the community who volunteered their services. Most of the women were former teachers or teachers in training. They were wives of town officials, businessmen, retired workers, public school teachers, and Mt. Holyoke College faculty members. Their only common interest was wanting to do something tangible that would improve the public school education of the children in the community. Generally a pair of volunteers was assigned to do all of the testing in the community on any one particular unit to minimize variability in test scores introduced by the evaluators. Word of the need for evaluators was given to several interested women who then organized the entire testing operation. Evaluators were specifically trained by the author for the units that they were going to evaluate. They made mutually convenient arrangements with the trial teachers for the individual-oral testing of the children. Roughly 500 children were tested twice between March and June of 1968 in the course of this research. The staggered basis of conducting units on any grade level that was used to minimize the material costs also served to even out the work loads of the evaluators. At first one might wonder why the trial teachers did not do the testing themselves. Practically, the time involved (five minutes per individual student) was too great. Actually the arrangements were quite satisfactory, and were even better from a public relations standpoint.

In addition to collecting data relative to the dependent variables, IQ, sex, and socio-economic information were obtained for each student so that an analysis of their influence on the pupil dependent variables could be assessed. Changes in pupil science attitude and other types of incidental learning were not investigated since the study was short-lived in any one classroom. Data on certain dependent variables (1, 3, 5, 6, and 7) were obtained at the end of each unit. Data on the other dependent variables (2 and 4) were obtained only after the second unit.

Data on teacher characteristics (science attitude, science background, and verbal control over activities) were recorded as descriptive background data. No interactions between the independent variables were studied due to the classroom confounding aspect.

Each of the 24 teachers presented two suitable, locally developed units (about three lessons each). Ideas for suitable units were found by scanning materials now being produced by nationally known elementary school science curriculum development groups (AAAS, ESS, ESSP, SCIS). The criteria for selection of unit ideas were adaptability of the ideas to both types of instructional aid conditions (minimal and additional), reasonableness of cost of large quantities of materials, materials presently on hand, and easy commercial availability of required new material. The trial units themselves (Appendix B) were written from September, 1967 to February, 1968 in a standard format giving behavioral objectives, materials needed, specific teaching instructions, and a time schedule to be followed for each lesson. Lessons were normally taught in the afternoon at a time convenient to the teacher. The lessons were written specifically for the materials that were going to be provided to the teacher. Materials that were not easily available locally were ordered from commercial sources in January, 1968. Girls from the high school business department typed the ditto masters for the units and boys in the high school industrial arts program made some of the needed materials. Kits for the trial units were delivered to and collected from the trial teachers on a prearranged schedule by the author to foster rapport.

Once the experimental period of the research began the author spent most of his time in face to face relationships with individuals involved in the research. The situation was similar to that of a mechanic trying to keep a delicate piece of complex machinery in operation. There were on the order of sixty individuals playing some role in the research. Each of the individuals was kept informed as to how things were going and assured that his role, no matter how small it was, was important to the smooth operation of the entire program.

Eight-millimeter movies and video tapes were made of the various phases of the research. The camera men (also volunteers) were high school chemistry teachers who borrowed equipment at various times from the School of Education at the University of Massachusetts, the Department of Psychology and Education at Mt. Holyoke College and a commercial dealer in Holyoke, Massachusetts. The movies and video tapes were used for reports to the community on the research sponsored by the Know Your Town women's group in May, 1968 in the cafetorium of the Intermediate School and a Parent Teacher Association program in the auditorium of Woodlawn School during American Education Week in November, 1968.

Statistical computations were done during August, 1968, by the computing center at Cornell University at government expense. Standard procedures for a randomized-incomplete block design were followed (Winer, 1962) using the standard library programs, analysis of variance for factorial design and cross tabulation with variable stacking, developed by the Health Sciences Computing Facility at the University of California at Los Angeles.

CHAPTER V

RESULTS

Factorial designs are used in experimentation in two general kinds of situations. The first, and probably most common, is that in which the purpose of the experiment is to establish the presence of an interaction if it does exist. The second is that in which there is no reason to suppose, in advance of the experiment, that the factors are inter-dependent, and in which the major purpose in using the factorial design is to make multiple use of the experimental material. This experiment falls in the second category.

An interaction will exist if the rank order of categories under study varies from one classification to another. As an illustration, if training teachers produced a positive effect in classrooms with additional instructional aids but a negative effect in classrooms with minimal instructional aids, then an interaction would exist between training and amount of instructional aids. Since in this particular design each classroom was used twice under exactly opposing conditions to counterbalance teachers and classes, any interactions that may really have existed became confounded with real classroom differences. Whenever classes are given treatments which are the same in one characteristic but different in another, the statistical treatment of the data will indicate that an interaction exists if one group of classes happens to be better than another group of classes. If the two groups are significantly different then the indicated interaction will be significant. Since there was no provision to equate the classes used in the experiment any comparison of classes taken at random runs the risk of comparing unbalanced groups. The counterbalancing is achieved only when the main independent variables are compared. At first one would think that an analysis of covariance (factorial design) with an adjustment of scores for IQ differences would have been a more appropriate statistical procedure but actually the most important factor in this problem is the teacher. The analysis of covariance cannot easily adjust for differences in teacher ability. The object of this discussion is to warn the reader that not all interactions that may seem to be indicated by the statistical treatment can be given weight no matter how significant they may appear to be.

Similarly any differences between units have been confounded with the different tests that were used and the different evaluating personnel that were used for each test. Any significant difference that might be found between two units might be due to the units, tests, or testers. In any case since two different units were used at any grade level the fact that pupils have scores which are significantly different between the two units is to be expected and is not part of this research.

The analysis of variance table for Grade 1 (Figure 2) shows that there is no significant difference between the student test results depending upon the order of the units ($F = 1.25/2.79 = 0.45$, $df = 1/304$). There is, however, a significant difference in student performance between those classes having additional instructional aids and those with minimal instructional aids ($F = 12.01/2.79 = 4.31$, $df = 1/304$, $p < .05$).

Teacher in-service training improved student performance approaching significance ($F = 8.45/2.79 = 3.03$, $df = 1/304$, $p < .10$). Any interactions which may look significant must be ignored because, as mentioned previously, there is confounding with classroom differences. Tables of means for selected first order interactions at all grade levels are provided in the appendix for study by interested readers. All testing for significant differences has been done using the within-replicates variance as the best estimate of error. This decision is justified by the fact that interaction variances are confounded.

The analysis of variance table for Grade 3 (Figure 3) shows again that the order of lessons makes no significant difference in student test performance ($F = 0.315/2.66 = 0.12$, $df = 1/368$). This time there is a decided reduction in the improvement of student performance produced by having additional instructional aids. The difference in performance between categories is minimal and decidedly not significant ($F = 1.38/2.66 = 0.32$, $df = 1/368$). Similarly the in-service training produces very little improvement in classroom performance and certainly not a significant difference ($F = 1.38/2.66 = 0.52$, $df = 1/368$).

The comments made about the Grade 1 results (locations of tables of means for interactions, use of the within replicates variance, and confounding) hold equally well for this table (Figure 3) and the one for Grade 6.

The analysis of variance table for Grade 6 (Figure 4) shows, as did the tables for the other two grades, that there is no significant difference produced depending upon the order of the units ($F = 0.31/3.62 = .09$, $df = 1/368$). As with Grade 3 the additional instructional aids produces a minimal, but not significant, improvement in student performance ($F = 0.32/3.62$, $df = 1/368$). The in-service training of teachers has a negative effect on student performance which approaches significance ($F = 13.12/3.61 = 3.72$, $df = 1/368$, $p < .10$).

Figure (2)

Analysis of Variance for Factorial Design-Grade 1

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares
1	1	1.25000	1.25000
2	1	117.61246	117.61246
3	1	12.01251	12.01251
4	1	8.44999	8.44999
12	1	40.61248	40.61247
13	1	5.51251	5.51251
14	1	1.80000	1.80000
23	1	4.05005	4.05005
24	1	6.61255	6.61255
34	1	0.61251	0.61251
123	1	0.45003	0.45003
124	1	1.01255	1.01255
134	1	0.61252	0.61252
234	1	0.44997	0.44997
1234	1	48.07718	48.07718
Within Replicates	304	850.87280	2.79892
Total	319	1100.00000	

Source of Variation	Categories	Means
1. Order of unit	1. First	6.81250
	2. Second	6.68750
2. Unit	1. Seeds	6.14375
	2. Classification	7.35625
3. Amount of Instructional Aids	1. Additional Instructional Aids Supplied	6.94375
	2. Mimimum Instructional Aids Supplied	6.55625
4. In-Service Training	1. Teacher Trained	6.91250
	2. Teacher Not Trained	6.58750

Figure (3)

Analysis of Variance for Factorial Design-Grade 3

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares
1	1	0.31510	0.31510
2	1	177.39835	177.39835
3	1	1.37760	1.37760
4	1	1.37761	1.37761
12	1	17.94012	17.94011
13	1	4.81510	4.81510
14	1	43.33593	43.33592
23	1	0.58596	0.58596
24	1	11.00264	11.00264
34	1	0.02344	0.02344
123	1	3.96091	3.96091
124	1	7.31510	7.31510
134	1	3.19011	3.19011
234	1	3.96092	3.96092
1234	1	0.02710	0.02710
Within Replicates	368	977.27051	2.65563
Total	383	1253.89551	

Source of Variation	Categories	Means
1. Order of unit	1. First	5.76042
	2. Second	5.81771
2. Unit	1. Temperature	6.46875
	2. Time	5.10937
3. Amount of Instructional Aids	1. Additional Instructional Aids Supplied	5.84896
	2. Minimum Instructional Aids Supplied	5.72917
4. In-Service Training	1. Teacher Trained	5.84896
	2. Teacher Not Trained	5.72917

Figure (4)

Analysis of Variance for Factorial Design-Grade 6

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares
1	1	0.31511	0.31511
2	1	2.19011	2.19011
3	1	0.31510	0.31510
4	1	13.12759	13.12759
12	1	0.02344	0.02344
13	1	30.94009	30.94009
14	1	17.08595	17.08595
23	1	0.58594	0.58594
24	1	0.31511	0.31511
34	1	17.94008	17.94008
123	1	5.75262	5.75262
124	1	0.02345	0.02345
134	1	7.31514	7.31514
234	1	26.56514	26.56512
1234	1	0.01668	0.01668
Within Replicates	368	1331.01831	3.61690
Total	383	1453.52979	

Source of Variation	Categories	Means
1. Order of unit	1. First	7.22916
	2. Second	7.17187
2. Unit	1. Water	7.12500
	2. Energy	7.27604
3. Amount of Instructional	1. Additional Instructional Aids Supplied	7.22916
	2. Minimum Instructional Aids Supplied	7.17187
4. In-Service Training	1. Teacher Trained	7.01562
	2. Teacher Not Trained	7.38541

Summarized, the results of this experiment are as follows:

1. Additional instructional aids result in significantly higher pupil achievement on subject matter tests only at the first grade level. No significant difference was found at other levels.
2. Specific teacher training did not produce significantly different pupil achievement.
3. Pupils with higher IQ's did significantly better on three of the six tests than those with lower IQ's (Appendix A.1).
4. There was no significant difference in achievement between boys and girls (Appendix A.2).
5. There was no significant difference in achievement between students from families in more privileged occupations and those from less privileged occupations. (Appendix A.3). Privileged occupations in this research are defined as higher executives, proprietors of large concerns, major professions, business managers, proprietors of medium-sized businesses, lesser professionals, clerical and sales workers, technicians, and owners of small businesses. Less privileged occupations are defined as manually skilled employees, machine operators, and semi-skilled employees, and unskilled employees. These divisions divided the student population into two approximately equal-sized groups.
6. Pupils preferred units having additional instructional aids over those with minimal aids at all grade levels (Figure 5). The differences were significant at the third grade level and highly significant at the sixth grade level.
7. There was no significant difference in preference for units (additional aids vs. minimal aids) between lower IQ pupils and higher IQ pupils (Appendix A.4).
8. In almost all units there were no significant differences in teacher time involvement (preparation, teaching, clean-up) as a result of training or additional aids (Figure 6).
9. Teachers did not think that in-service training was necessary even though many expressed the feeling that they would prefer to have it (Figure 7).
10. Teachers generally did not think that student text materials would improve the units (Figure 7).
11. Teachers had overwhelmingly favorable reactions to both the materials and the methods used in the units (Figure 7).
12. Most teachers did not repeat demonstrations so there are not enough data to evaluate the number of repetitions variable (Figure 7).

Figure (5)

Instructional Aids Preference

Grade	Unit Preferred according to Instructional Aids Supplied Minimal	Additional	Binomial Test z =	Comments
1	77	83	-0.39	No Significant Difference
3	81	111	-2.1	Significant Difference $p < .02$ (one-tailed)
6	70	120	-3.7	Significant Difference $p < .0002$ (one-tailed)

All students were exposed to two units. One had additional instructional aids supplied so that the children could work simultaneously in small groups of two to four students and have ample opportunity to interact with the materials and other students. The other unit had minimal instructional aids supplied so that lessons were normally of the demonstration variety supplemented by various exercises and activities in which the children would take turns manipulating the laboratory materials. Students were simply asked which unit they liked best.

Figure (6)

Teacher Preparation Time (Minutes)

Unit	Median	Range
A. Seeds	48	34-95
B. Classification	73	15-120
C. Temperature	48	20-60
D. Time	38	20-60
E. Water	60	13-300
F. Energy	65	45-165

No significant differences were found between trained and untrained teachers or between teachers having minimal and additional instructional aids using the Fisher exact probability test except in Unit B. In that unit the untrained teachers took a significantly longer amount of time to prepare their lessons ($p = .025$).

Classroom Teaching Time (Minutes)

Unit	Median	Range
A. Seeds	150	25-600
B. Classification	126	60-330
C. Temperature	110	90-130
D. Time	103	75-205
E. Water	177	110-270
F. Energy	275	180-450

No significant differences were found between trained and untrained teachers or between teachers having minimal and additional instructional aids using the Fisher exact probability test.

Classroom Clean-up Time (Minutes)

Unit	Median	Range
A. Seeds	27	10-50
B. Classification	20	5-120
C. Temperature	15	6-20
D. Time	11	0-30
E. Water	45	16-90
F. Energy	20	10-50

No significant differences were found between trained and untrained teachers or between teachers having minimal and additional instructional aids using the Fisher exact probability test except in Unit F. In that unit the teachers having additional instructional aids took a significantly longer time to clean up their classrooms ($p = .05$).

Figure (7)

Teacher Opinions

Question	Data	Comments (One-tailed binomial test)
Is training necessary?		
Trained group	8 yes, 16 no	No significant difference
Untrained group	6 yes, 17 no	Significant difference $p < .02$
Total group	14 yes, 33 no	Significant difference $p < .005$
What is your reaction to the materials?	21 favorable 1 unfavorable	Significant difference $p < .001$
What is your reaction to the teaching methods?	18 favorable 3 unfavorable	Significant difference $p < .001$
Would a student text improve the unit?	11 yes, 36 no	Significant difference $p < .0003$
Were demonstrations repeated?	18 yes, 30 no	No significant difference but approaching $p = .05$.

Figure 8 shows some descriptive information on the teachers taking part in this study. Generally they indicated that they liked science, had a median of 12 semester hours of college credit in science courses, and controlled activity type science lessons differently according to the grade being taught. Lower grade teachers generally had all groups doing each part of the activity simultaneously on specific teacher direction while upper grade teachers had the groups proceeding at different rates giving guidance and help separately to the groups.

Tables showing the relation of IQ, sex, and family occupation classification to test scores and amount of instructional aids preference are provided in the appendix for the interested reader. These relations have already been summarized in this chapter. Though interesting to many, they are not worthy of much consideration since the tables do not necessarily represent data from balanced groups. Taken in total, though, they do provide a general picture as given in the summary of results.

Figure (8)

Descriptive Information on Teachers Taking Part in Study

How do you like science in comparison to other subject that you teach?

12 prefer it to other subjects
5 about the same as other subjects
7 prefer other subjects to science

How many semester hours of college credit in science courses do you have? Do not include courses in how to teach science.

Median - 12 semester hours
Range - 0-30 semester hours

During an activity type science lesson, how do you generally maintain control over the activity?

	Grade 1	Grade 3	Grade 6
All groups do each part of the activity simultaneously on specific direction from you.	5	2	0
Mixed reactions written in.	2	3	0
All groups proceed at different rates through the activity getting help and guidance separately from you.	1	3	8

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

Some of the results of this experiment indicate that the opinion of Piaget is correct at the lower grade levels while other results indicate that the opinion of Ausubel is correct beyond the third grade level. Piaget advocates active manipulation and social collaboration rather than demonstrations. Ausubel suggests that didactic verbal exposition combined with demonstrations and exercises is sufficient in many cases. Concrete empirical props in the form of demonstrations and exercises provided sufficient non-verbal experience for learning at the third and sixth grade levels. At the first grade level, though, these demonstrations and exercises were not as effective; sufficient instructional aids for individual manipulation in small groups resulted in superior learning. Although significant improvement in instruction did not occur with additional aids at the third and sixth grade levels, students overwhelmingly preferred units having these additional instructional aids. This preference makes it desirable to have additional aids at the upper elementary school levels in spite of the fact that the additional aids do not seem to be necessary.

As practical guidelines for school systems it is recommended that sufficient additional instructional aids be provided for the first few elementary grades so that students can interact with materials and other students in small groups. The economics of the situation dictate that in the rest of the elementary grades, when the materials are expensive, minimal amounts should be purchased. When the materials are not costly, in the upper elementary grades additional amounts of instructional aids should be purchased to satisfy student preferences.

The results seem to indicate that in-service training of the type used in this research is not beneficial. As a reminder to the reader the instruction consisted of a description of each activity in the unit followed by first hand experience, under supervision, doing the same things with the same material that the pupils would do in the unit. Considering that a significant number of teachers did not feel that the in-service training was necessary and that it never did make any significant difference, it is the author's opinion that the teachers' guides provided with the NSF supported elementary science programs are effective with elementary school teachers who do not have special in-service training. This finding may prove to be a blessing in disguise for local school systems. If a serious in-service training program were necessary then implementation of the new elementary science curricula would be difficult since most local systems are not in a position to offer such training. This kind of in-service training is not even available at most teacher training institutions. If little or no in-service training is necessary then the implementation problem becomes one of acquainting teachers and administrators with the new curricula. One implementation plan suggested by Mr. Frank Watson of Elementary Science Study during recent conversations with the author calls for forming a small group of volunteers to micro-teach with new curriculum materials during a summer school and then to use these same materials in their own classes the following school year. They would be given sufficient time to acquaint themselves with the new materials prior to the summer school. The next summer and following school year another small group of volunteers would go through the same process. Only after the majority of teachers are already using the new materials should administrators move toward complete system-wide adoption.

Another plan suggested by Mr. Alan Humphreys of the Minnesota Mathematics and Science Teaching project calls for the training of a seed group of teachers at an approved MINNEMAST summer training program and then the utilization of this seed group to implement the program in a local school system. In conversations with the author in August, 1968, both Mr. Watson and Mr. Humphreys agreed that the new elementary science curricula were not academically difficult for teachers. They did feel as though teachers probably would require some adjustment to the teaching methods and philosophies. This adjustment can be made easier by administrators and science coordinators who encourage rather than force teachers to try the new curriculum materials. If the teacher-administrator atmosphere is healthy there should be no real problem implementing new curricula.

It would seem that the operation of an expensive, locally designed, in-service program to institute new elementary science programs is not economically justifiable on the part of school systems. This is not to say that local teacher training institutions should not offer in-service courses for those teachers who desire the training or that school systems should not use the packaged in-service programs being developed by the new curricula. It is rather an indication that the kind of in-service instruction that a local school system might design themselves probably would be a waste of public funds. Design of extensive worthwhile in-service programs to institute new science programs is a complex problem and apparently needs study. A co-operative effort between school systems and colleges is needed to design worthwhile programs to implement the new elementary science curricula.

An example of the kind of cooperative effort that is necessary occurred during the last two weeks of August, 1968, when the Massachusetts State Department of Education held a workshopconference on new elementary science curricula. Faculty members from the Massachusetts State Colleges, the University of Massachusetts, and representatives of school systems within commuting distance of each of the colleges were represented. As an outcome of this conference regional teams of college faculty members and representatives of school systems were formed to oversee the implementation and dissemination of information on new elementary science curricula in various areas in the state. Most regional teams have seen the need to establish "seed" communities using the new curricula as part of the general implementation problem. Each team is using whatever scheme seems appropriate to establish "seed" communities in their region.

South Hadley, the community used in this research, will be one of the "seed" communities in western Massachusetts. As a direct outcome of this research project about half of the elementary teachers in the community have had some direct experience with material-oriented, non-textbook, science units. On the basis of their experience the local science curriculum committee has decided to institute a material-oriented elementary science curriculum in the community schools. The specific nature of the new science curriculum is presently a matter of discussion by the committee and, via its representatives, the entire elementary school teaching staff, the elementary school administrators, and members of the school committee. There has only been one curriculum decision made thus far. It must be a material-oriented curriculum. Monthly workshops are being held to acquaint the elementary school faculty with AAAS, ESS, MINNEMAST, and SCIS materials. In addition the committee meets several times a month to generate plans and to discuss problems. The current plans of the committee are to operate a two week special summer science school during the summer of 1969. Funds for trial materials and teacher salaries have been voted by the school committee for the 1969 fiscal budget.

The purpose of the summer school will be to give twelve to fourteen teachers first-hand experience teaching materials that the committee selects. These teachers will work in pairs, one pair per class, with classes of twelve to fifteen students. It can be considered that the special summer school is giving pairs of teachers an opportunity to work out their teaching techniques with new science materials prior to using them in their own classrooms. There will be no formal in-service training in connection with this summer school since the teachers' guides are considered to be sufficient on the basis of this research project. However, the summer school teachers will have consultant help available on the premises for several hours a day while they are not teaching in case there are individual problems. It is hoped that the limited experience that these teachers will have during the summer school will be sufficient to overcome any reservations that they may have about their ability to handle the new curriculum materials.

These same teachers will be encouraged to serve as trial teachers for the materials that the curriculum committee selects during the next school year. On the basis of their experiences with these teachers the science curriculum committee will make further plans for the implementation of the newly selected curriculum next year. It is anticipated that the following summer the science curriculum committee will sponsor another summer school in which more teachers can gain experience with new materials before they use them in their own classrooms. During the second summer school some of the experienced teachers from the previous year will serve as consultants.

It is the author's opinion that the implementation problem is basically one of overcoming teacher and administrative anxiety and not a teacher training problem. The problem of implementation then is really a problem of convincing the accepted leader in science education in each community that the new materials are better than the old. This accepted leader can probably shepherd a new program through the maze of barriers. College faculty members who are concerned about improving public school science education should do everything within their power to foster rapport between themselves and the accepted education leaders in the public schools. These comments probably hold equally well in areas other than elementary school science. This is the kind of co-operative effort between school systems and colleges that is needed to implement the new elementary science curricula. It is a very personal co-operative effort between concerned individuals on different academic levels.

In summary, at the present time it seems as if there really is no academic reason why elementary teachers cannot teach the new elementary science materials. They like the materials, the students like them, and the materials do seem to be successful at least in the lower elementary grades. In-service training does not seem to be necessary. The big stumbling block seems to be overcoming human inertia. What is really needed is a program to fire-up the teachers' and administrators' interest. This research project did so in South Hadley.

APPENDIX A.1

Test Scores vs. IQ

In the following tables the scores refer to the number of points that a student received on a ten point individual oral examination of how well he had achieved the behavioral objectives of the unit. The actual tests used are in Appendix C.

Unit A - Seeds
Unit B - Classification
Unit C - Temperature
Unit D - Time
Unit E - Water
Unit F - Energy

APPENDIX A.1

Test Scores (frequency) vs. IQ

Test A (Grade 1) Seeds

Score	IQ 1. Upper	2. Lower
10	3	3
9	6	2
8	18	16
7	10	7
6	14	27
5	9	7
4	4	22
3	2	5
2	1	3
1	0	1

Chi-Square of Table 19.04411
Degrees of Freedom 9 $P < .025$
Correlation Coefficient -0.2598

Test B (Grade 1) Classification

Score	IQ 1. Upper	2. Lower
10	6	4
9	15	13
8	18	23
7	19	24
6	6	12
5	1	12
4	1	2
3	1	2
2	0	1

Chi-Square of Table 10.76679
Degrees of Freedom 8
Correlation Coefficient -0.2194

Test C (Grade 3) Temperature

Score	IQ 1. Upper	2. Lower
10	3	2
9	4	3
8	29	14
7	13	7
6	57	28
5	9	5
4	6	7
3	1	2
2	1	1

Chi-Square of Table 3.94738
Degrees of Freedom 8
Correlation Coefficient -0.0688

Test Scores (frequency)vs. IQ (Continued)

Test D (Grade 3) Time

	IQ	
Score	1. Upper	2. Lower
10	3	0
9	4	0
8	10	4
7	16	7
6	27	7
5	24	12
4	16	21
3	17	13
2	6	3
1	0	2

Chi-Square of Table 19.41513
Degrees of Freedom $P < .025$
Correlation Coefficient -0.2259

Test E (Grade 6) Water

	IQ	
Score	1. Upper	2. Lower
10	24	11
9	4	2
8	51	11
7	3	6
6	30	17
5	2	3
4	12	8
3	2	2
2	1	2

Chi-Square of Table 15.65441
Degrees of Freedom 8 $P < .025$
Correlation Coefficient -0.1324

Test F (Grade 6) Energy

	IQ	
Score	1. Upper	2. Lower
10	19	6
9	23	6
8	24	7
7	29	16
6	20	11
5	10	10
4	3	2
3	1	4
2	1	0

Chi-Square of Table 12.95868
Degrees of Freedom 8
Correlation Coefficient -0.2055

APPENDIX A.2

Test Scores vs. Sex

In the following tables the scores refer to the number of points that a student received on a ten point individual oral examination of how well he had achieved the behavioral objectives of the unit. The actual tests used are in Appendix C.

Unit A - Seeds

Unit B - Classification

Unit C - Temperature

Unit D - Time

Unit E - Water

Unit F - Energy

APPENDIX A.2

Test Scores (frequency) vs. Sex

Test A (Grade 1) Seeds

Score	Sex 1. Male	2. Female
10	3	3
9	5	3
8	16	18
7	9	8
6	21	20
5	5	11
4	11	15
3	2	5
2	1	3
1	1	0

Chi-Square of Table 5.98562
Degrees of Freedom 9
Correlation Coefficient -0.1003

Test B (Grade 1) Classification

Score	Sex 1. Male	2. Female
10	1	9
9	11	17
8	19	22
7	22	21
6	9	9
5	8	5
4	1	2
3	3	0
2	0	1

Chi-Square of Table 12.12230
Degrees of Freedom 8
Correlation Coefficient 0.1789

Test C (Grade 3) Temperature

Score	Sex 1. Male	2. Female
10	3	2
9	3	4
8	29	14
7	9	11
6	41	44
5	5	9
4	8	5
3	1	2
2	0	2

Chi-Square of Table 9.87193
Degrees of Freedom 8
Correlation Coefficient -0.1243

Test Scores (frequency) vs. Sex (Continued)

Test D (Grade 3) Time		
Score	Sex 1. Male	2. Female
10	3	0
9	3	1
8	10	4
7	11	12
6	17	17
5	19	17
4	21	16
3	11	19
2	4	5
1	0	2

Chi-Square of Table 11.46983
Degrees of Freedom 9
Correlation Coefficient -0.1698

Test E (Grade 6) Water		
Score	Sex 1. Male	2. Female
10	23	12
9	4	2
8	33	29
7	5	4
6	28	19
5	1	4
4	9	11
3	3	1
2	2	1

Chi-Square of Table 6.38689
Degrees of Freedom 8
Correlation Coefficient -0.0882

Test F (Grade 6) Energy		
Score	Sex 1. Male	2. Female
10	17	8
9	19	10
8	14	17
7	25	20
6	19	12
5	13	7
4	0	5
3	1	4
2	0	1

Chi-Square of Table 15.29866
Degrees of Freedom 8 $P < .10$
Correlation Coefficient -0.1415

APPENDIX A.3

Test Scores vs. Family Occupation Classification

In the following tables the scores refer to the number of points that a student received on a ten point individual oral examination of how well he had achieved the behavioral objectives of the unit. The actual tests used are in Appendix C.

Higher family occupation classifications in this research are defined as higher executives, proprietors of large concerns, major professions, business managers, proprietors of medium-sized business, lesser professionals, administrative personnel, owners of small independent businesses, minor professionals, clerical and sales workers, technicians, and owners of little businesses. Lower classifications are skilled manual employees, machine operators, semi-skilled employees, and unskilled employees.

Unit A - Seeds
Unit B - Classification
Unit C - Temperature
Unit D - Time
Unit E - Water
Unit F - Energy

APPENDIX A.3

Test Scores (frequency) vs. Family Occupation Classification (Higher-toward executive end of scale Lower-toward unskilled end of scale)

Test A (Grade 1) Seeds

Score	Family Occupation Classification 1. Higher	 2. Lower
10	6	0
9	7	1
8	18	16
7	11	6
6	22	19
5	6	10
4	7	19
3	4	3
2	2	2
1	0	1

Chi-Square of Table 19.79189
Degrees of Freedom 9 $P < .025$
Correlation Coefficient -0.2611

Test B (Grade 1) Classification

Score	Family Occupation Classification 1. Higher	 2. Lower
10	5	5
9	14	14
8	23	18
7	25	18
6	10	8
5	3	10
4	1	2
3	1	2
2	1	0

Chi-Square of Table 7.19252
Degrees of Freedom 8
Correlation Coefficient -0.0673

Test C (Grade 3) Temperature

Score	Family Occupation Classification 1. Higher	 2. Lower
10	2	3
9	5	2
8	30	13
7	12	8
6	50	35
5	7	7
4	3	10
3	1	2
2	1	1

Chi-Square of Table 11.34576
Degrees of Freedom 8
Correlation Coefficient -0.1642

Test Scores (Frequency) vs. Family Occupation Classification
(Higher-toward executive end of scale
Lower-toward unskilled end of scale)

Test 3 (Grade 3) Time	Family Occupation Classification	
Score	1. Higher	2. Lower
10	3	0
9	3	1
8	10	4
7	15	8
6	24	16
5	15	23
4	19	18
3	16	14
2	3	4
1	1	1

Chi-Square of Table 11.32708
Degrees of Freedom 9
Correlation Coefficient -0.1613

Test 2 (Grade 7) Water	Family Occupation Classification	
Score	1. Higher	2. Lower
10	23	12
9	6	5
8	31	35
7	3	6
6	22	15
5	5	3
4	4	11
3	3	4
2	5	6

Chi-Square of Table 7.53138
Degrees of Freedom 8
Correlation Coefficient -0.0592

Test 5 (Grade 6) Energy	Family Occupation Classification	
Score	1. Higher	2. Lower
10	13	10
9	17	15
8	17	16
7	26	19
6	17	14
5	8	10
4	4	5
3	4	3
2	1	3

Chi-Square of Table 4.12992
Degrees of Freedom 8
Correlation Coefficient -0.1109

APPENDIX A.4

Instructional Aids Preference vs. IQ

As a rough generalization, a classroom supplied with minimal amounts of laboratory instructional aids received about the same amount of material in total as was provided to a small group of four students in the classroom supplied with additional amounts of aids.

APPENDIX A.4

Instructional Aids Preference (frequency) vs. IQ

Grade 1

Preference	IQ 1. Upper	2. Lower
2. Minimal	35	42
1. Additional	32	51

Chi-Square of table 0.78139
Degrees of Freedom 1
Correlation Coefficient -0.0699

Grade 3

Preference	IQ 1. Upper	2. Lower
2. Minimal	53	28
1. Additional	70	41

Chi-Square of Table 0.11416
Degrees of Freedom 1
Correlation Coefficient -0.0244

Grade 6

Preference	IQ 1. Upper	2. Lower
2. Minimal	49	21
1. Additional	81	41

Chi-Square of Table 0.26461
Degrees of Freedom 1
Correlation Coefficient -0.0371

APPENDIX A.5

Instructional Aids Preference vs. Sex

As a rough generalization, a classroom supplied with minimal amounts of laboratory instructional aids received about the same amount of material in total as was provided to a small group of four students in the classroom supplied with additional amounts of aids.

APPENDIX A.5

Instructional Aids Preference (frequency) vs. Sex

Grade 1

	Sex	
Preference	1. Male	2. Female
2. Minimal	34	43
1. Additional	40	43

Chi-Square of Table 0.26185
Degrees of Freedom 1
Correlation Coefficient 0.0405

Grade 3

	Sex	
Preference	1. Male	2. Female
2. Minimal	40	41
1. Additional	59	52

Chi-Square of Table 0.26655
Degrees of Freedom 1
Correlation Coefficient 0.0373

Grade 6

Preference	1. Male	2. Female
2. Minimal	44	26
1. Additional	64	58

Chi-Square of Table 1.95419
Degrees of Freedom 1
Correlation Coefficient -0.1009

APPENDIX A.6

Instructional Aids Preference vs. Family Occupation Classification

As a rough generalization, a classroom supplied with minimal amounts of laboratory instructional aids received about the same amount of material in total as was provided to a small group of four students in the classroom supplied with additional amounts of aids.

Higher family occupation classifications in this research are defined as higher executives, proprietors of large concerns, major professions, business managers, proprietors of medium-sized business, lesser professionals, administrative personnel, owners of small independent businesses, minor professionals, clerical and sales workers, technicians, and owners of little businesses. Lower classifications are skilled manual employees, machine operators, semi-skilled employees, and unskilled employees.

APPENDIX A.6

Instructional Aids Preference (freq.) vs. Family Occupation Classification
(Higher-toward executive end of scale
Lower-toward unskilled end of scale)

Grade 1

Preference	Family Occupation Classification 1. Higher	2. Lower
2. Minimal	42	35
1. Additional	41	42

Chi-Square of Table 0.42401
Degrees of Freedom 1
Correlation Coefficient

Grade 3

Preference	Family Occupation Classification 1. Higher	2. Lower
2. Minimal	52	29
1. Additional	59	52

Chi-Square of Table 2.34198
Degrees of Freedom 1
Correlation Coefficient -0.1104

Grade 6

Preference	Family Occupation Classification 1. Higher	2. Lower
2. Minimal	33	37
1. Additional	71	51

Chi-Square of Table 2.18913
Degrees of Freedom 1
Correlation Coefficient 0.1068

APPENDIX A.7

Tables of Means for Selected
First Order Interactions-Grade 1

	Unit	
Order	1. Seeds	2. Classification
1. First	6.56250	7.06250
2. Second	5.72500	7.65000

	Instructional Aids	
Unit	1. Additional	2. Minimal
1. Seeds	6.22500	6.06250
2. Classification	7.66250	7.05000

	In-Service Training	
Unit	1. Trained	2. Not-Trained
1. Seeds	6.45000	5.83750
2. Classification	7.37500	7.33750

Tables of Means for Selected First Order Interactions-Grade 3

	Unit	
Order	1. Temperature	2. Time
1. First	6.65625	4.86458
2. Second	6.28125	5.35417

	In-Service Training	
Order	1. Trained	2. Not Trained
1. First	6.15625	5.36458
2. Second	5.54167	6.09375

	In-Service Training	
Unit	1. Trained	2. Not Trained
1. Temperature	6.69792	6.23958
2. Time	5.00000	5.21875

	Instructional Aids	
Unit	1. Additional	2. Minimal
1. Temperature	6.48958	6.44792
2. Time	5.20833	5.01042

Tables of Means for Selected First Order Interactions-Grade 6

	Instructional Aids	
Order	1. Additional	2. Minimal
1. First	7.54167	6.91667
2. Second	6.91667	7.42708

	In-Service Training	
Order	1. Trained	2. Not Trained
1. First	6.83333	7.62500
2. Second	7.19792	7.14583

	In-Service Training	
Instructional Aids	1. Trained	2. Not Trained
1. Additional	7.26042	7.19792
2. Minimal	6.77083	7.57292

	In-Service Training	
Unit	1. Trained	2. Not Trained
1. Water	6.96875	7.28125
2. Energy	7.06250	7.48958

	Instructional Aids	
Unit	1. Additional	2. Minimal
1. Water	7.11458	7.13542
2. Energy	7.34375	7.20833

APPENDIX B.1

Experimental Units for First Grade

Seeds

Adapted from material published in
Botany for Beginners in Science, Teacher's Manual,
by Herbert L. Mason and Myrtle R. Wolf
for the Elementary School Science Project,
University of California in 1966.

Teachers' Guide

Unit title-Seed Germination

Grade level - 1

Type instruction--Small groups of students working with large amounts of material.

Time schedule
Day 1 Activity 1 begin
Day 2 Activity 1 end
Day 3 Activity 2 begin
Day 4 Activity 3 begin
Day 5, 7, 9,...17 Activity 2 observations
Day 6, 8, 10,...18 Activity 3 observations
[No observations on weekends]
Day 17 Activity 2 concluded
Day 18 Activity 3 concluded
Day 19, 20, Individual testing of students

Background

A seed is a resting stage of a plant. When the right moisture and temperature conditions occur the plant embryo developes roots, a stem, leaves and finally flowers.

The purpose of this unit is to teach children some facts concerning:

1. The environmental conditions that will terminate the dormant stage of a plant.
2. The direction of growth of the parts of a seedling.
3. The rate of growth of a plant.

The unit will also provide the children experience working with simple experimental design, recording of data, and graphing techniques.

CAUTION: Keep seeds, seedling, and plants out of direct sunlight and away from radiators to avoid drying them out.

Activity 1

Objective: Given a collection of seeds which have not been sprouted a student will be able to tell which ones have started to grow.

Grouping size - 2 students per group

Materials:
4 cups (small, waxed, paper) per group
4 Bush snap bean seeds per group
1 cardboard carton (minimum dimensions 1½ ft. x 1½ ft. x 6 in.) per class
1 lens per group to be used as a magnifier
1 razor blade per class

There are several environmental conditions that children might expect to have an influence on the development of seeds in a classroom. Two of these are moisture and light. This suggests that four experimental conditions need to be investigated. These are:

1. No moisture-no light.
2. Moisture-no light.
3. No moisture-light.
4. Moisture-light.

Each group of students is to be given 4 small paper cups and 4 bean seeds (one for each cup). Each of the cups should be marked as to ownership and experimental conditions that it is to undergo. One convenient way to do this is to have the group members mark the cups with their initials and either words like no moisture-no light or symbols like ML, M̸L, ML̸, M̸L̸. Those seeds, destined for the moisture conditions are to have their cups half filled with water so that those seeds will have a thorough soaking. Those destined for the no light conditions are to be put in a closet or under a cardboard carton.

The next day give each group a lens. Ask the students to use the lens to look at their finger, objects on their desk, and hair on the back of their hands. When you are sure that the children know how to use the lens as a magnifier have the children carefully examine the seeds from the previous day to see if there are any changes. Each group is to work on its own seeds. Each cup is to be placed on a separate piece of paper and the seed that it contained broken open on the same piece of paper in front of the cup. This way the students are not so likely to mix-up the seeds and it will be easier for them to keep track of which seed had which experimental condition. Teachers may have to use a razor blade to open dry seeds for the children.

The examination of the seeds is to be followed immediately with a class discussion of the experimental results. Ask questions such as:

1. Which seeds had something happen?
   (Moisture-light, moisture-no light)
2. What was done to the seeds that had something happen?
   (Moisture)
3. What happened to these seeds?
   (Parts swelled)

The teacher must be sure to operate at first-grade level during the discussion. Unfamiliar vocabulary should not be used. Any disagreements between groups should be resolved into two categories--personal errors in procedure and problems with the seeds. If there were any procedural errors ask the children how these errors might be avoided in future investigations. If there were any seed problems ask the children to suggest reasons why these problems occurred. (The seeds may be dead.)

Activity 2

Objective: Given a seed which is just sprouting a student will be able to identify the root and stem.

Grouping size - 2 students per group

Materials:
1 small glass jar or cup per group
4 Bush snap bean seeds per group (presoaked for 24 hours)
1 paper towel per group
1 bag of vermiculite per class
4 data sheets per student
1 eye dropper per class

Have each group of students place a ring of moistened paper towel around the inside of a small glass jar or cup. They are to fill the central core of the jar with vermiculite. 4 bean seeds are to be placed in various orientations (upright, inverted, sideways) around the ring between the paper toweling and the glass. The contents of the jars should be gently watered and the vermiculite kept damp throughout the activity by the addition of several eye droppers full of water each day. The seeds should be marked for identification purposes by pasting numbers (1, 2, 3, 4) on the outside of the jar next to each seed. In addition each jar should be marked by the initials of the student that prepared the jar.

A demonstration by the teacher in front of the class will help to make the instructions clear. Students are to make a drawing of the appearance of each seed in their jar every two days for 2 weeks on the data sheets provided to them. This can be done individually during any free time.

On the last day of observations the class is to discuss the results of the experiment. Ask questions like:

1. Which comes first--roots or stems? (Roots)
2. Does the position of the seed make any difference? (No)
3. What happens if the root comes out the top or the stem comes out the bottom? (After two weeks it should be obvious that the stem curves up and the root curves down.)
4. How does the appearance of the roots differ from that of the stems? (Roots are hairy.)
5. What is the advantage of keeping records of observations over a long period of time? (It makes it easier to study events that occur slowly.)

Data Sheet of Activity 2

Name
Jar
Seed Number

Date	Picture	Date	Picture

Activity 3

Objective: Given a plant the students will be able to generate and interpret a graph of growth vs time for the plant.

Grouping size - 2 students per group

Materials:
1 Bush snap bean plant in a paper cup per group
(Plants have been started about a week ahead of time.)
1 sheet of specially designed graph paper per group
Narrow strips colored paper
Paste
1 paper clip per group
1 eye dropper per class

Each group of students is to make an identification mark on its plant and to measure the length of its plant above the soil level every two days for two weeks by cutting a paper strip the same length as the plant. Each strip should be marked for identification purposes by initials of students in the group and the date. This can be done individually during any free time. The collection of strips for each group can be kept together by a paper clip and kept in a safe place by the teacher. Students should be assigned to give the plants a little water (enough to moisten the soil) with an eye dropper each day and keep them away from direct sunlight and radiators.

On the last day of observations the groups are to paste their strips on the specially designed graph paper. The strips are to be pasted above the appropriate day. If a measurement was not made on a particular day then the space for that day should be left blank. When the pasting is done ask the children questions like:

1. Do they all grow the same amount each day? (No)
2. Did the plants grow faster in the beginning or at the end of the experiment? (Look at the increase from one day to the next.)
3. How should we measure the length if the plant is curved? (Follow the curvature of the plant.)
4. Does the plant ever get smaller? (No)
5. Does it ever stay the same? (No)

Special Graph Paper for
Activity 3

Name________________________

Plant________________________

Date	Plant Length

Put colored strips in these boxes with one end against the double line.

Teachers' Guide

Unit title-Seed Germination

Grade level - 1

Type instruction--Entire class of students working with limited amounts of material.

Time schedule

Day 1 Activity 1 begin
Day 2 Activity 1 end
Day 3 Activity 2 begin
Day 4 Activity 3 begin
Day 5, 7, 9,...17 Activity 2 observations
Day 6, 8, 10,...18 Activity 3 observations
[No observations on weekends.]
Day 17 Activity 2 concluded
Day 18 Activity 3 concluded
Day 19, 20 Individual testing of students

Background

A seed is a resting stage of a plant. When the right moisture and temperature conditions occur the plant embryo develops roots, a stem, leaves and finally flowers.

The purpose of this unit is to teach children some facts concerning:

1. The environmental conditions that will terminate the dormant stage of a plant.
2. The directions of growth of the parts of a seedling.
3. The rate of growth of a plant.

The unit will also provide the children experience working with simple experimental design, recording of data, and graphing techniques.

CAUTION: Keep seeds, seedlings, and plants out of direct sunlight and away from radiators to avoid drying them out.

Activity 1

Objective: Given a collection of seeds which have not sprouted a student will be able to tell which ones have started to grow.

Materials:
- 8 cups (small, waxed, paper) per class
- 8 Bush snap bean seeds per class
- 1 cardboard carton (minimum dimensions 1 ft. x 1 ft. x 6 in.)
- 2 lenses per class to be used as a magnifier
- 1 razor blade per class

There are several environmental conditions that children might expect to have an influence on the development of seeds in a classroom. Two of these are moisture and light. This suggests that four experimental conditions need to be investigated. These are:

1. No moisture-no light
2. Moisture-no light.
3. No moisture-light.
4. Moisture-light.

Have a group or 8 volunteers put 8 bean seeds into 8 small paper cups (one seed per cup.) Each of the cups should be marked as to ownership and experimental conditions that it is to undergo. There will be two cups with seeds undergoing each experimental condition. One convenient way to do this is to have each student volunteer mark his cup with his initials and either words like no moisture-no light or symbols like ML, M̸L, ML̸, M̸L̸. You will have to allocate the assigned conditions among the student volunteers. Those seeds destined for the moisture conditions are to have their cups half filled with water so that these seeds will have a thorough soaking. Those destined for the no light conditions are to be put in a closet or under a cardboard carton.

The next day pass around the two lens. Ask the students to use the lens to look at their fingers, objects on their desk, and hair on the back of their hands. Some students can be doing this while others are doing other class work such as reading. Later in the day when you are sure that the children know how to use a lens as a magnifier have the volunteers from the previous day arrange two displays of seeds that have undergone the four experimental conditions. Each cup is to be placed on a separate piece of paper and the seed that it contained broken open on the same piece of paper in front of the cup. This way the students are not solikely to mix up the seeds and it will be easier for them to keep track of which seed had which experimental condition. Teachers may have to use a razor blade to open dry seeds for the children. Place a lens next to each display and have some children carefully examine the seeds to see if there are any changes.

Let as many children as care to take turns examining the seeds.

The examination of the seeds is to be followed immediately with a class discussion of the experimental results. Ask questions such as:

1. Which seeds had something happen?
   (Moisture-light, moisture-no light)
2. What was done to the seeds that had something happen?
   (Moisture)
3. What happened to these seeds?
   (Parts swelled)

The teacher must be sure to operate at first-grade level during the discussion. Unfamiliar vocabulary should not be used. Any disagreements between students should be resolved into two categories--personal errors in procedure and problems with the seeds. If there were any procedural errors ask the children how these errors might be avoided in future investigations. If there were any seed problems ask the children to suggest reasons why these problems occurred. (The seeds may be dead.) The displays are to be left up for the rest of the day and the children encouraged to examine the seeds as much as they want during their free time.

Activity 2

Objective: Given a seed which is just sprouting a student will be able to identify the root and stem.

Materials:
- 3 small glass jars or cups per group
- 4 Bush snap bean seeds per jar (presoaked for 24 hours)
- 1 paper towel per jar
- 1 bag of vermiculite per class
- 4 data sheets per student
- 1 eye dropper per class

Select two student volunteers from the class. Have each volunteer place a ring of moistened paper towel around the inside of a small glass jar or cup. They are to fill the central core of the jar with vermiculite. 4 bean seeds are to be placed in various orientations (upright, inverted, sideways) around the ring between the paper toweling and the glass. The contents of the jars should be gently watered and the vermiculite kept damp throughout the activity by the addition of several eye droppers full of water each day. The seeds should be marked for identification purposes by pasting numbers (1, 2, 3, 4) on the outside of the jar next to each seed. In addition each jar should be marked by the initials of the student that prepared the jar.

A demonstration by the teacher in front of the class using the third jar will help to make the instructions clear. Students are to make a drawing of the appearance of each seed in an assigned jar every two days for 2 weeks on the data sheets provided to them. This can be done individually during any free time.

On the last day of observations the class is to discuss the results of the experiment. Ask questions like:

1. Which comes first--roots or stems? (Roots)
2. Does the position of the seed make any difference? (No)
3. What happens if the root comes out the top or the stem comes out the bottom? (After two weeks it should be obvious that the stem curves up and the root curves down.)
4. How does the appearance of the roots differ from that of the stems? (Roots are hairy.)
5. What is the advantage of keeping records of observarions over a long period of time? (It makes it easier to study events that occur slowly.)

Data Sheet of Activity 2

Name______________________________
Jar_______________________________
Seed Number_______________________

Date	Picture

Date	Picture

Activity 3

Objective: Given a plant the student will be able to generate and interpret a graph of height of growth vs time for the plant.

Materials: 3 Bush snap bean plants in a paper cup per class (Plants have been started about a week ahead of time.) 1 sheet of specially designed graph paper per student.
Narrow strips of colored paper
Paste
1 paper clip per student
1 eye dropper per class

Each plant is to be marked with a different letter for identification. Assign each student to one of the three plants and have him measure the length of his plant above the soil level every two days for two weeks by cutting a paper strip the same length as the plant. Each strip should be marked for identification purposes by initials of student and the date. This can be done individually during any free time.

The collection of strips for each student can be kept together by a paper clip and kept in a safe place by the teacher. Students should be assigned to give the plants a little water (enough to moisten the soil) with an eye dropper each day and keep them away from direct sunlight and radiators.

On the last day of observations the students are to paste their strips on the specially designed graph paper. The strips are to be pasted above the appropriate day. If a measurement was not made on a particular day then the space for that day should be left blank. When the pasting is done ask the children questions like:

1. Do they all grow the same amount each day? (No)
2. Did the plants grow faster in the beginning or at the end of the experiment? (Look at the increase from one day to the next.)
3. How should we measure the length if the plant curved? (Follow the curvature of the plant.)
4. Does the plant ever get smaller? (No)
5. Does it ever stay the same? (No)

Special Graph Paper for
Activity 3

Name____________________

Plant____________________

Date	Plant Length

Put colored strips in these boxes with one end against the double line.

APPENDIX B.2

Experimental Units for First Grade

Classification

Adapted from materials published in

Science--A Process Approach

by American Association for the Advancement of Science, Washington, 1967

and in Material Objects by Science Curriculum Improvement Study

University of California, 1968

Teachers' Guide

Unit Title - Classification

Grade Level - 1

Type Instruction - Small groups of students working with large amounts of material

Time Schedule

Day 1 Activity 1 begin
Day 2 Activity 1 end
Day 3 Activity 2 begin and end
Day 4 Activity 3 begin
Day 5 Activity 3 end
Day 6, 7 Individual testing of students

Background

Objects can be classified according to many criteria such as size, shape, color, texture, and type of material. Classification is one of the more basic processes that a scientist uses. Although we commonly think of it in connection with the biological sciences it is a common characteristic of all sciences. Identification and classification of objects is normally based on observable characteristics. This unit will provide exposure to the problem of classification and direct the attention of children to some observable classification characteristics.

Activity 1

Objective: Given a set of colored tablets of various shapes the student will be able to separate objects by shapes and color.

Grouping size - 3 or 4 students per group

Materials: 1 box (320 pieces per box) of colored tablets with shapes of circles, squares, triangles and half circles in 8 colors per class.
1 bag (large paper) per group

In this activity the children will play a matching game with colored tablets of various shapes. In advance of the activity put either 27 or 36 colored tablets (amount depends upon whether the group size is 3 or 4) into a large paper bag for each group. Use only two colors per bag and make sure that the shapes are varied.

When the game starts give a bag of tablets to each group. Have every child in each group draw five tablets from the bag without looking into it. Now have every child match the pairs in his possession that are alike in all respects (color and shape). Those pairs that are matched are to be set aside.

After this is done each child, when he has his turn, is to draw out one tablet from the bag. If it matches one of the tablets already in his possession he is to set aside the matched pair and pass the bag on to the next contestant. If it does not match, he is to return one tablet (not necessarily the one just picked) to the bag and pass the bag on to the next contestant in the group. The winner of the round in any group is the one who first retires all of his tablets. The game is continued for several rounds.

When the children can play the basic game well, changes in the rules are to be introduced. To stress arithmetic learnings you may stipulate that only sets of three matched objects can be retired or you may allow the children to take and discard two tablets at a time instead of one. To stress science learnings you may require that only the color or the shape of the tablets must match. Try games of each type described.

In order to derive any benefit from playing the game, the groups of children should clearly understand the rules. Your judgement is needed in order to decide when your help in explanation of the rules is really necessary.

Activity 2

Objectives: Given a set of shapes made of various materials and in various shapes and colors the student will be able to separate the shapes according to selected criteria.

Grouping Size - 2 or 3 students per group

Materials: For each group
Shapes-One each of the following cut from white tag stock: circle, eclipse, triangle, square, rectangle.
Shapes-One each of the following cut from white construction paper: circle, eclipse, triangle, square, rectangle, heart, star, quadrilateral.
Shapes-One or two of the following cut from colored cloth: circle, ellipse, triangle, square, rectangle.
Shapes-Three of different colors cut from colored construction paper.

Distribute the shapes to each group. Ask one person in each group to sort the materials into two piles based on the curviness and flatness of edges. Hold a discussion on the results to see if everyone has the right idea. Now ask another partner in each group to sort the objects in some other way. Be completely non-directive and let each child choose his own criterion for sorting. Ask each child to tell how he sorted his objects. One pupil's method of sorting can be adopted as a way for everyone to sort his objects. Members of each group are to take turns doing the sorting. A discussion of various criteria for sorting should follow the activity.

Some criteria for sorting are:

1. Curviness and flatness of sides.
2. Specific material and not specific material.
3. Square corners and not square corners.
4. Indented edges and not indented edges.
5. Hollow and not hollow.
6. Colored and not colored.
7. Specific color and not specific color.
8. Symmetrical and not symmetrical.
9. Length and width alike and not alike.
10. Edges forming points and edges not forming points.
11. Those that look the same when turned over and those that do not.
12. Those that look the same when turned $\frac{1}{4}$ a turn and those that do not.

Activity 3

Objective: Given a set of blocks of four types of wood the student will be able to separate the blocks as to types that are of the same wood.

Grouping Size - Individually

Materials: 4 large (1 ft. x 3 in. x 1 in.) tagged, and identified samples of pine, maple, birch, and mahogony per class.

50 pieces each of the same kinds of wood of almost the same size and shape per class.

12 lenses suitable for use as magnifying glasses per class.

Before starting this activity pass out the lenses and have the children use them to look at objects on their desks, fingers, clothes, and printing in their books. The most convenient way of holding the lens is holding opposite edges between the thumb and forefinger. This technique should be demonstrated to the children.

Divide the pieces of wood ahead of time into 4 piles. Each pile should contain all four kinds of wood. Ask each child to come up to a pile and take six objects from it. Allow them to make their selections in any way that they like. Have them place the pieces they have selected on their desks and carefully examine them. The children are to determine the similarities and differences between the pieces that they have selected. Next tell them to sort their wood into two piles according to some method that they choose. Ask the class to observe other individual sortings to see if they can decide what method was used by the individual.

Now ask the children to sort their collection into as many piles as necessary in order to have only one kind of wood in each pile. After the sorting has taken place tell the children that there are at least 4 kinds of wood in the piles. Show them a large piece of each of the four kinds of wood. Hold up each large tagged sample of wood, identify it by name, and have the children tell you about its characteristics. Ask each individual to hold up a piece of wood he thinks is the same kind as the one you are showing him. Check the choices visually and ask one or two leading questions of individuals who have made obviously wrong choices.
(Does your wood have the same color as mine? The same kind of lines in it as mine? Does it feel the same? Smell the same?)

The children will enjoy trying to identify samples with their eyes closed by feeling and smelling. Have everyone get a complete collection of all four kinds of wood by trading with neighbors or returning to the wood piles. Have a few of the children who think that they can identify the wood with their eyes closed demonstrate their skill to the class. Leave the materials around the classroom for a few days so that pupils who wish to do so can get more experience sorting wood.

Teachers' Guide

Unit Title - Classification

Grade Level - 1

Type Instruction - Entire class of students working with limited amounts of material.

Time Schedule
Day 1 Activity 1 begin
Day 2 Activity 1 end
Day 3 Activity 2 begin and end
Day 4 Activity 3 begin
Day 5 Activity 3 end
Day 6, 7 Individual testing of students

Background

Objects can be classified according to many criteria such as size, shape, color, texture, and type of material. Classification is one of the more basic processes that a scientist uses. Although we commonly think of it in connection with the biological sciences it is a common characteristic of all sciences. Identification and classification of objects is normally based on observable characteristics. This unit will provide exposure to the problems of classification and direct the attention of children to some observable classification characteristics.

Activity 1

Objective: Given a set of colored tablets of various shapes a student will be able to separate objects by shape and color.

Materials: 1 box containing 32 matched pairs of colored tablets with shapes of circles, squares, triangles, and half circles in 8 colors per class
2 bags (large paper) per class

In this activity the children will play a matching game with colored tablets of various shapes. In advance of the game put one of each of the matched tablets into a large paper bag and the other into a second large paper bag. Divide the class into two teams. Line up both teams as in a spelling bee. Pass around the first bag and have each child draw one tablet from the bag without looking into it.

To play the game now pass the second bag from one team to the other down the lines of children. In his turn each child is to draw one tablet from the second bag without looking. If it matches one of the tablets of any of his team members, he is to exchange his original piece for that of his team mate and return to his seat with the matched pair. If the tablet he draws matches the one already in his possession he is just to return to his seat with the pair. If it does not match, he completes his turn by returning the tablet to the bag. The winning team is the one that can first retire all its members. The bag will probably have to make several trips down the lines before any team is completely retired. The game is to be played several times.

When the children can play the basic game well, changes in the rules are to be introduced. To stress arithmetic learnings you may allow the children to take two tablets at a time from the second bag and return those that do not match. To stress science learnings you may require that only the color or the shape of the tablets must match. Try games of each type described.

In order to derive any benefit from playing the game, the group of children should clearly understand the rules. Your judgement is needed in order to decide when your help in explanation of the rules is really necessary.

Activity 2

Objective: Given a set of shapes made of various materials and in various shapes and colors the student will be able to separate the shapes according to selected criteria.

Materials: For each class
Shapes - One each of the following cut from white tag stock: circle, ellipse, triangle, square, rectangle.
Shapes - One each of the following cut from white construction paper: circle, ellipse, triangle, square, rectangle, heart, star, quadrilateral.
Shapes - One of each of the following cut from colored cloth: circle, ellipse, triangle, square, rectangle.
Shapes - Two of the following made from wire (not all groups): circle, ellipse, triangle, square, rectangle.
Shapes - Ten of different colors cut from colored construction paper.

Distribute the shapes to the class so that each student has one. Tell the class that you are going to ask them questions about their shapes. Ask everyone who has a shape with a curved side to hold it up. Demonstrate what you mean by curved edge by a picture using the chalkboard. If anyone is wrong, see if you can make him understand why he is in error. Now ask the ones with flat sides to hold up their shapes and check as before. Have the children exchange shapes and try the same line of questioning as before. Repeat this activity several times until you are reasonably sure that the children know the differences between curviness and flatness.

Now ask the class to suggest other ways in which some of the shapes may be the same. When a new way is offered have the class members hold up the shapes that first fit the new way and second do not. Each time check to see if there are errors. Keep track on the chalkboard of all the different ways that are suggested. See how long a list the class can make.

Some of the ways in which the shapes are the same and different are:

1. Curviness and flatness of sides.
2. Specific material and not specific material.
3. Square corners and not square corners.
4. Indented edges and not indented edges.
5. Hollow and not hollow.

6. Colored and not colored.
7. Specific color and not specific color.
8. Symmetrical and not symmetrical.
9. Length and width alike and not alike.
10. Edges forming points and edges not forming points.
11. Those that look the same when turned over and those that do not.
12. Those that look the same when turned $\frac{1}{4}$ a turn and those that do not.

Activity 3

Objective: Given a set of blocks of 4 types of wood the student will be able to separate the blocks as to types that are of the same wood.

Materials:
- 4 large (1 ft. x 3 in. x 1 in.), tagged, and identified samples of pine, maple, birch and mahogany per class.
- 6 small pieces each of the kinds of wood of almost the same size and shape per class.
- 6 lenses suitable for use as magnifying glasses per class.

Before starting this activity pass out the lenses and have the children use them to look at objects on their desk: fingers, clothes, and printing in their books. The most convenient way of holding the lens is holding opposite edges between the thumb and forefinger. This technique should be demonstrated to the children.

Distribute the 6 small samples of pine and 6 lenses (1 sample and lens). Holding the large sample of pine in front of the class point out identifying characteristics (color, grain, aroma.) Drill the children in the name of the wood. Print the name on the chalkboard. Allow the children sufficient time to pass around the small samples and examine them.

When all have observed the pine samples distribute 6 small samples of maple. Like before hold the large sample in front of the class pointing out identifying characteristics (color, grain, aroma). Drill the children in the name of this wood and print its name also on the chalkboard.

Now show both large pieces of wood together. Show how they are different. Have the children carefully examine both small pieces together to note the differences. Some children may be able to identify samples with their eyes closed by feeling and smelling. If you mention this fact to the class this will encourage them to try this technique.

Continue the same procedure with the remaining types of wood until both identifying characteristics and differences have been pointed out. By this time the children should be able to identify any sample by name. As a review have each child hold one piece of wood in his hand. Hold up a large sample of wood and move around so that all can examine it but cannot see any identification markings. Ask everyone in the class who thinks that he has the same kind of wood to hold it up. Check the choices visually and ask one or two leading questions of individuals who have obviously made the wrong choice. (Does your wood have the same color as mine? The same kind of lines in it as mine? Does it feel the same? Smell the same?) Have the children exchange samples. If there are not enough samples to go around make sure that those who did not get samples last time do so this time. Try the same review question again with each other sample of wood. Leave the materials around the classroom for a few days so that pupils who wish to do so can get more experience sorting wood.

APPENDIX B.3

Experimental Units for Third Grade

Temperature

Adapted from materials published in
Temperature, by Science Curriculum Improvement Study,
University of California, 1963.

Teachers' Guide

Unit title-Temperature

Grade level - 3

Type instruction--Small groups of students working with large amounts of material.

Time schedule
Day 1 Activity 1
Day 2 Activity 2
Day 3 Activity 3
Day 4, 5 Individual testing of students

Background

In this unit the children will become accustomed to reading Celsius (old Centigrade) thermometers and predicting what will happen to the thermometer readings in different situations. Temperature is a measure of one of the characteristics of a material. A good operational definition is that temperature is a measure of how cold or hot something is. Every student will fill out a special data sheet for each activity to provide a later reminder of events in the activity. They are to be retained by the student and disposed of as he sees fit at the end of the unit.

Activity 1

Objectives: Given a Celsius thermometer a student will be able to read the thermometer to within 1 degree.

Given a Celsius thermometer a student will know that the reading will go up if the thermometer is made warmer and down if the thermometer is made cooler.

Grouping size - 2 students per group

Materials:
- 1 Celsius thermometer per group
- 1 special data sheet #1 per student
- 1 plastic foam coffee cup per group
- 1 quart of rubbing alcohol per class

In this activity the students are going to try a few simple experiments with a Celsius (old Centigrade) thermometer. Distribute one thermometer to each group for the students to examine. Conduct a class discussion centered on how to read the thermometer. The discussion should cover such topics as:

What is the value of each line? (2 degrees)
How are the readings between lines interpreted? (one degree higher than the value of the line just below)

The children need to be able to read the thermometer to the closest degree. A few sample pictures on the chalkboard will help to get across the idea of how to read the thermometer.

When you are sure that the children know how to read the thermometer pass out the special data sheets. Have all groups do each experiment together. Read the directions to the students. Discuss each experiment before going on to the next. Distribute a small amount of alcohol in a plastic foam cup to each group for the third experiment.

Thermometer-Special Data Sheet 1

Name________________

Date________________

Experiment 1

The temperature reading of the thermometer at the beginning of the experiment is________.

Hold the bulb between your thumb and forefinger. Count to five. What is the temperature reading now?________

Hold the bulb between your thumb and forefinger. Count to forty. The temperature reading is now at________.

Hold the bulb again. Count to one hundred. The temperature reading now is________.

What would be the temperature reading if you held the bulb even longer?________

Experiment 2

Now close your fist around the thermometer. Let the top end stick out. Count to forty. The temperature reading is at ________.

Put down the thermometer and rub your hands together fast. What do you feel? ________

Now try to make the temperature reading higher than normal in your fist by rubbing your hands together fast before holding the thermometer. How high did you make the temperature reading go? ________

Experiment 3

Put the thermometer bulb into the small amount of alcohol and leave it there. Count to twenty. The temperature reading is at ________.

Take the thermometer out of the alcohol and put it on your desk. Slowly count to thirty. The temperature reading now is at ____.

Put a little alcohol on your finger and wave it back and forth. What do you feel? ____________

Now try to make the temperature reading lower than normal by first dipping the thermometer bulb in the alcohol and then waving the thermometer back and forth. How low did you make the temperature reading go? ________

Activity 2

Objectives: Given the temperature reading of one thermometer in a material a student will be able to predict the temperature reading of a second thermometer in the same material.

Given several thermometers a student will be able to assign a temperature reading to a material.

Grouping size - 4 students per group

Materials:
3 plastic foam coffee cups (marked #1, #2, and #3 for identification), each having water at a different temperature per group
1 Celsius thermometer per student
1 special data sheet #2 per student

In this activity each student will take special custody of a thermometer and observe how it acts in contact with water at various temperatures in three cups. In the previous activity the students saw how a thermometer behaved in contact with fingers, hands, and alcohol. This time they will think about the temperature of the material that is in contact with the thermometer.

Distribute the materials to the groups. Put hot, lukewarm, and cold water in the cups. For safety do not use water that is too hot to keep your finger in. Even though the instructions are given on the special data sheets the details of the procedures are to be gone over ahead of time so that each student knows what he is going to do ahead of time.

When the experiment is completed and the questions on the data sheet have been answered conduct a class discussion on the answers to the questions to resolve any conflicts and misinterpretations. When thermometers do not quite agree on the temperature of a material then the average of the readings best represents how hot or cold the material is.

Special Data Sheet #2

Name____________________
Date____________________

Have three marked cups containing water. In this activity you will find out something about the water in each cup. You will do this by letting a thermometer come in contact with the water in each cup.

To start, put two of the thermometers into cup #1 and the rest into cup #2. The temperature readings of the thermometers placed in cup #1 are _________. The temperature readings of the thermometers placed in cup #2 are _________.

Now put all the thermometers into cup #3. Observe the temperature readings of all the thermometers. Do the thermometers show evidence of being influenced by the water in cup #3?________ Count to thirty. The temperature readings of the thermometers are_________.

Now answer the following questions:

1. How close were the temperature readings in cup #1?

____
(the same, almost the same, very different)

2. How close were the temperature readings in cup #2?

____
(the same, almost the same, very different)

3. How close were the temperature readings in cup #3?

____
(the same, almost the same, very different)

Now that you know the temperature readings of the thermometers that are in cup #3 what temperature reading, do you think, best represents how hot or cold the water is that cup is?

____________________.

Activity 3

Objectives: Given the temperature reading of one thermometer in a material a student will be able to predict the temperature reading of a second identical thermometer in the same material.

After observing temperature readings in two equal samples of water at different temperatures a student will be able to predict the temperature reading that will be observed if the samples are mixed.

Grouping size - 2 students per group

Materials:
2 foam plastic coffee cups per group
1 Celsius thermometer per group
1 special data sheet #3 per student
hot and cold water ($\frac{1}{4}$ cup of each per group)

In this activity the students will predict the reading that will be indicated by a thermometer in three situations. To help them in making their predictions they will have the benefit of other thermometer readings taken in advance.

Distribute the materials to the groups. Even though the instructions are given on the special data sheets the details of the procedures are to be gone over ahead of time so that each student knows what he is going to do ahead of time. For safety do not use water that is too hot to keep you finger in.

When each section is completed and the questions on the data sheet have been answered conduct a class discussion on the answers to the questions to resolve any conflicts and misinterpretations before going on to the next section of the activity.

When thermometers do not quite agree on the temperature of a material then the average of the readings best represents how hot or cold the material is. The addition of warm water to cold water will result in a mixture with a higher temperature than that of just cold water. When equal amounts of warm and cold water are mixed the final temperature will be midway between the original temperatures of the samples of water.

Special Data Sheet #3

Name________________

Date________________

In this experiment you will have a chance to predict the temperature reading of a thermometer. To start the experiment, get some cold water in a plastic foam coffee cup. Get an equal amount of warm water in another similar cup.

Choose one of the plastic cups of water. Put just ONE of your thermometers in the water. Wait until the temperature reading stops changing. The final temperature reading is_____.

Leave the thermometer in the water. Try to predict what the temperature reading of a second thermometer will be after it is put in the same water. The predicted temperature reading for the second thermometer is_________.

Now put the second thermometer in the water alongside the first. Wait until its temperature reading stops changing. The final temperature reading of the second thermometer is______.

Is the temperature reading of the second thermometer close to what you predicted?______________.

Record the temperature readings of both thermometers. ______________ What temperature reading, do you think best represents how hot or cold the water in that cup is?__________

Now do the same experiment over again with the other cup of water. Record your answers in the same blanks above but underline them to keep them separate from the old answers.

What do you think will be the temperature reading of a thermometer put into the partially emptied cup of warm water? ______________Try it. What was the temperature reading?______

You can do another experiment with both cups of water. What do you think will happen to the temperature reading of a thermometer in the cold water if a little warm water is added to the cold water?___________Try it. What happened to the temperature reading of that thermometer?

What do you think the temperature reading of the same thermometer will be if all of the warm water is added to the cold so that equal amounts of warm and cold water are mixed?______ Try it. What was the actual temperature reading of the thermometer?__________________

Is there any connection between the mixture temperature reading and the temperature readings of the warm and cold water?

____

Teachers' Guide

Unit Title - Temperature

Grade Level - 3

Type instruction - Entire class of students with limited amounts
of material.

Time Schedule
Day 1 Activity 1
Day 2 Activity 2
Day 3 Activity 3
Day 4, 5 Individual testing of students

Background

In this unit the children will become accustomed to reading Celsius (old Centigrade) thermometers and predicting what will happen to the thermometer readings in different situations. Temperature is a measure of one of the characteristics of a material. A good operational definition is that temperature is a measure of how cold or hot something is. Every student will fill out a special data sheet for each activity to provide a later reminder of events in the activity. They are to be retained by the student and disposed of as he sees fit at the end of the unit.

Activity 1

Objectives: Given a Celsius thermometer a student will be able to read the thermometer to within 1 degree.

Given a Celsius thermometer a student will know that the reading will go up if the thermometer is made warmer and down if the thermometer is made cooler.

Materials:
4 Celsius thermometers per class
1 special data sheet #1 per student
1 plastic foam coffee cup per class
2 ounces of rubbing alcohol per class

In this activity the class is going to try a few simple experiments with a Celsius (old Centigrade) thermometer. Distribute the thermometers to the class for the students to examine. Conduct a class discussion centered on how to read the thermometer. The discussion should cover such topics as:

What is the value of each line? (2 degrees)
How are readings in between lines interpreted? (One degree higher than the value of the line just below)

The children need to be able to read the thermometer to the closest degree. A few sample pictures on the chalkboard will help to get across the idea of how to read the thermometer.

When you are sure that the children know how to read the thermometers pass out the special data sheets. Use two student assistants for each experiment. They can take turns doing the experiment and thereby give the class two answers for each question on the data sheet. Use different assistants for each experiment.

Read the directions to the class for each experiment ahead of time. Discuss each experiment before going on to the next. For experiment number 3 you will have to put a little rubbing alcohol into the plastic foam cup.

Leave the materials available in the classroom and encourage the students to examine them and repeat the experiments individually during free time.

Thermometer--Special Data Sheet 1

Name____________________

Date____________________

Experiment 1

The temperature reading of the thermometer at the beginning of the experiment is __________.

Hold the bulb between your thumb and forefinger. Count to five. What is the temperature reading now?__________

Hold the bulb between your thumb and forefinger. Count to forty. The temperature reading is now at__________.

Hold the bulb again. Count to one hundred. The temperature reading now is__________.

What would be the temperature reading if you held the bulb even longer?__________

Experiment 2

Now close your fist around the thermometer. Let the top end stick out. Count to forty. The temperature reading is at_______.

Put down the thermometer and rub your hands together fast. What do you feel?__________

Now try to make the temperature reading higher than normal in your fist by rubbing your hands together fast before holding the thermometer. How high did you make the temperature go?__________

Experiment 3

Put the thermometer bulb into the small amount of alcohol and leave it there. Count to twenty. The temperature reading is at__________.

Take the thermometer out of the alcohol and put it on your desk. Slowly count to thirty. The temperature reading now is at__________.

Put a little alcohol on your finger and wave it back and forth. What do you feel?____________________

Now try to make the temperature reading lower than normal by first dipping the thermometer bulb in the alcohol and then waving the thermometer back and forth. How low did you make the temperature reading go?__________________

Activity 2

Objectives:	Given the temperature reading of one thermometer in a material a student will be able to predict the temperature reading of a second thermometer in the same material. Given several thermometers a student will be able to assign a temperature reading to a material.
Materials:	3 plastic foam coffee cups (marked #1, #2, and #3 for identification), each having water at a different temperature per class 4 Celsius thermometers per class 1 special data sheet #2 per student

In the previous activity the students saw how a thermometer behaved in contact with fingers, hands, and alcohol. This time they will think about the temperature of the material that is in contact with the thermometer.

Select 4 assistants to help you with the experiment. Let each one take special charge of one of the thermometers. Put hot, lukewarm, and cold water in the cups. For safety do not use water that is too hot to keep your finger in. Even though the instructions are given on the special data sheets the details of the procedures are to be gone over ahead of time so that each student knows what is going to be done. Repeat the experiment at least one more time with another group of assistants.

When the experiment is completed and the questions on the data sheet have been answered conduct a class discussion on the answers to the questions to resolve any conflicts and misinterpretations. When thermometers do not quite agree on the temperature of a material then the average of the readings best represents how hot or cold the material is.

Leave the materials available in the classroom and encourage the students to examine them and repeat the experiments individually during free time.

Special Data Sheet #2

Name ____________________

Date ____________________

You have three marked cups containing water. In this activity you will find out something about the water in each cup. You will do this by letting a thermometer come in contact with the water in each cup.

To start, put two of the thermometers into cup #1 and the rest into cup #2.

The temperature readings of the thermometers placed in cup #1 are ____________.

The temperature readings of the thermometers placed in cup #2 are ____________.

Now put all the thermometers into cup #3. Observe the temperature readings of all the thermometers. Do the thermometers show evidence of being influenced by the water in cup #3?

Count to thirty. The temperature readings of the thermometers are ____________.

Now answer the following questions:

1. How close were the temperature readings in cup #1?

   ____

   (the same, almost the same, very different)

2. How close were the temperature readings in cup #2?

   ____

   (the same, almost the same, very different)

3. How close were the temperature readings in cup #3?

   ____

   (the same, almost the same, very different)

Now that you know the temperature readings of the thermometers that are in cup #3 what temperature reading, do you think, best represents how hot or cold the water in that cup is?

____________________________.

Activity 3

Objectives: Given the temperature reading of one thermometer in a material a student will be able to predict the temperature reading of a second identical thermometer in the same material.

After observing temperature readings in two equal samples of water at different temperatures a student will be able to predict the temperature reading that will be observed if the samples are mixed.

Materials:
- 2 foam plastic coffee cups per group
- 1 Celsius thermometer per group
- 1 special data sheet #3 per student
- hot and cold water ($\frac{1}{4}$ cup of each per group)

In this activity the students will predict the reading that will be indicated by a thermometer in three situations. To help them in making their predictions they will have the benefit of other thermometer readings taken in advance.

Select two assistants to help you with the activity. Let each one take special charge of one of the thermometers. Put hot and cold water in the cups. For safety do not use water that is too hot to keep your finger in. Even though the instructions are given on the special data sheets the details of the procedure are to be gone over ahead of time so that everyone knows what is going on ahead of time. Have every student record his own predictions before the assistants announce the actual temperature readings.

When the activity is completed and the questions on the data sheet have been answered conduct a class discussion on the answers to the questions to resolve any conflicts and misinterpretations.

When thermometers do not quite agree on the temperature of a material then the average of the readings best represent how hot or cold the material is. The addition of warm water to cold water will result in a mixture with a higher temperature than that of just cold water. When equal amounts of warm and cold water are mixed the final temperature will be midway between the original temperatures of the samples of water.

Special Data Sheet #3

Name________________

Date________________

In this experiment you will have a chance to predict the temperature reading of a thermometer. To start the experiment, get some cold water in a plastic foam coffee cup. Get an equal amount of warm water in another similar cup.

Choose one of the plastic cups of water. Put just ONE of your thermometers in the water. Wait until the temperature reading stops changing. The final temperature reading is

____________.

Leave the thermometer in the water. Try to predict what the temperature reading of a second thermometer will be after it is put in the same water. The predicted temperature reading for the second thermometer is ____________.

Now put the second thermometer in the water alongside the first. Wait until its temperature reading stops changing. The final temperature reading of the second thermometer is________.

Is the temperature reading of the second thermometer close to what you predicted?____________

Record the temperature readings of both thermometers. ________What temperature reading do you think best represents how hot or cold the water in that cup is?____________

Now do the same experiment over again with the other cup of water. Record your answers in the same blanks above but underline them to keep them separate from the old answers.

What do you think will be the temperature reading of a thermometer put into the partially emptied cup of warm water? ____________Try it. What was the temperature reading?______

You can do another experiment with both cups of water. What do you think will happen to the temperature reading of a thermometer in the cold water if a little warm water is added to the cold water?________Try it. What happened to the temperature reading of that thermometer?____________

What do you think the temperature reading of the same thermometer will be if all of the warm water is added to the cold so that equal amounts of warm and cold water are mixed?________ Try it. What was the actual temperature reading of the thermometer?______________

Is there any connection between the mixture temperature reading and the temperature readings of the warm and cold water?

____

APPENDIX B.4

Experimental Units for Third Grade

Time

Adapted from materials published in

Science--A Process Approach by American Association for the

Advancement of Science, 1967

Teachers' Guide

Unit Title - Measuring Time Intervals

Grade Level - 3

Type Instruction - Small groups of students working with large amounts of material.

Time Schedule
    Day 1 Activity 1
    Day 2 Activity 2
    Day 3 Activity 3
    Day 4, 5 Individual testing of students

Background

Developing the idea of time and its measurement is of special importance for the child in the early grades. The meaning of arbitrary time standards used in our daily life, the relation of these standards to periodic astronomical phenomena, and the highly precise technique developed for measuring units of time in science, underlie this significant role.

An understanding of the ways by which time standards are chosen and calibrated provides insight into the general process of calibration in science. These brief experiments with water clocks and pendulums can be the point of departure for later valuable discussions of motions of the sun and moon, latitude, Greenwich time, sundials, and miscellaneous excursions into history and social studies.

Activity 1

Objective: Given events that occur reasonably often at uniform rates a student will be able to use these regular events as standards to time various activities.

Grouping size - 4 students per group

Materials:
6 marbles per group
2 small paper cups per group
1 pendulum about a foot long per class

Cover the faces of all clocks in the room and do not allow the children to use any watches during this activity. Ask two children in each group to take turns performing an activity such as picking up 6 marbles one at a time from one cup and putting them into another cup. Let the other members of the group decide who can do the task the fastest by silently counting in a regular fashion--one, two, three, etc. The winner is the one who can perform the task in the smallest number of counts. There should be some problem with counting rates in each group but let the students decide among themselves how they will do the counting. Ask each timer in the groups to record the number of counts that the winner takes to do the task. Now ask the group timers to determine if the winner can improve his speed with practice. After several opportunities to improve find out who is the class champion by asking each group timer to tell the class how many counts their winner could do the task in.

Now ask the class if they really believe that the class champion should be picked in this fashion. If the children do not bring up the possibility that each group may not be counting at the same rate then you bring up the point. Have the children look for examples of events that occur at uniform rates that could be used as counting guides (water drips, pulse, watch ticks, metronome, or pendulum.) Let one student be the master counter for the class using one of these kinds of guides. He can say something like "now" each time an event occurs. Each group can time their winner by counting along with the master counter.

Is the class champion the same as it was before when each timer counted the way that he chose? Conclude this activity with a class discussion of the problems of timing events as suggested by this activity (uniform counting of standard events).

Activity 2

Objective: Given some material that can flow from one container to another a student will be able to use the materials and containers to make a clock suitable for timing events.

Grouping size - 4 students per group

Materials:
- 1 empty frozen juice can (large) per group
- 1 soft drink bottle per group
- 1 crayon per group
- 1 quart plastic container per group
- 1 clock (or watch) with a second hand per class
- several sheets of newspapers per group

State that you will ask two students in turn to do a task for you. The task should be something that will take several minutes such as walking a round trip to some place in the building. Ask the children how they might determine which student takes the longest time to do the task. After a brief discussion of the ideas suggested by the students, let them break up into groups to prepare water clocks.

A water timer can be made from a tin can with a hole in the bottom made by a thumbtack, together with a soft drink bottle. If the can is set on top of the soft drink bottle the water level in the bottle will rise about an inch a minute as water drains into it from the can. To operate the water timer one child should hold the can with a finger over the hole in the bottom while another child fills the can with water. Several sheets of newspaper on the desk should take care of spills and a quart plastic container half filled with water should be suitable for pouring.

The first student should now be asked to carry out the designated task. At the signal to begin, the children are to place the punctured cans containing water over the soft drink bottle and allow the water to empty into the bottle. When the student returns from the task the timer is stopped by lifting the punctured can covering the hole with a finger. A crayon mark is to be made on the side of the bottle at the upper level of the water.

The cans are now to be refilled to the same levels as before and a second student sent on the same designated task. The same procedures are to be followed and at the end both crayon marks are to be compared to find out which student did the task in the shortest time.

Repeat the timing procedure for several other tasks to give the students more experience with their water timers.

Now let the children calibrate their timers with a clock. One student in a group can watch the hand on the clock and call out the minutes for others to mark with a crayon on the side of the bottle. If necessary one student can act as a class clock by signaling with his hand every time a minute goes by. A number of questions are to be asked about the water timer in a discussion that follows the activity. Does the water always run out through the hole at the same rate? (No, it runs out faster when the can is full.) How do you know this? How can we find out? (The minute marks on the bottle are farther apart at first and get closer together as the can empties.)

Activity 3

Objectives: A student will be able to measure small time intervals in seconds without the aid of timing devices. A student will be able to match a pendulum's period of swing to a timing device by adjusting the length of the pendulum.

Grouping size - 4 students per group

Materials:
- 1 small metal weight per group
- 1 two foot length of string per group
- 1 clock with a second hand per class

Have one student in each group construct a pendulum from the string and weight. Now have another student hold the pendulum string by loosely winding it around his finger. He is to allow the weight to swing freely and adjust the length of the string so that the weight makes about 10 complete round trips in 10 seconds. Someone in the class can call out the seconds while observing a clock to help the groups adjust their pendulums. When the groups are ready, let each group use its own "pendulum clock" to find the time interval between two events that take place in the classroom such as two claps of your hands.

Now have the students in each group count in unison with the swinging pendulum in their group, noting that there is a quiet period between each count. Ask: If we had longer words than one, two, three, four, etc. or were counting something with a long name like "steamboat," "elephant," or "chimpanzee," could we just about keep time with the "seconds" of the swinging pendulum? Have members of each group take turns counting the number of swings of their pendulum clock with their eyes closed to see who can do the best job of keeping time with the pendulum clock. Ask them if the size of the swing of the string makes any difference. (Negligible) Ask them if the length of the string makes any difference and in what way. (Longer lengths take longer times for a complete swing.)

Teachers' Guide

Unit Title - Measuring Time Intervals

Grade Level - 3

Type Instruction - Entire class of students working with limited amounts of material.

Time Schedule
    Day 1 Activity 1
    Day 2 Activity 2
    Day 3 Activity 3
    Day 4, 5 Individual testing of students

Background

Developing the idea of time and its measurement is of special importance for the child in the early grades. The meaning of arbitrary time standards used in our daily life, the relation of these standards to periodic astronomical phenomena, and the highly precise technique developed for measuring units of time in science, underlie this significant role.

An undertaking of the ways by which time standards are chosen and calibrated provides insight into the general process of calibration in science. These brief experiments with water clocks and pendulums can be the point of departure for later valuable discussions of motions of the sun and moon, latitude, Greenwich time, sundials, and miscellaneous excursions into history and social studies.

Activity 1

Objective: Given events that occur reasonably often at uniform rates a student will be able to use these regular events as standards to time various activities.

Materials:
6 marbles per class
2 small paper cups per class
1 pendulum about a foot long per class

Cover the faces of all clocks in the room and do not allow the children to use any watches during this activity. Ask two children to take turns in front of the class performing an activity such as picking up 6 marbles one at a time from one cup and putting them into another cup. Let the other member of the pair time the activity by silently counting in a regular fashion--one, two, three, etc. The winner is the one who can perform the task in the smallest number of counts. Try the same activity with several other pairs and pick a class champion. The class champion is the one who did the activity in the smallest number of counts.

Now ask the class if they really believe that the class champion should be picked in this fashion. If the children do not bring up the possibility that each timer may not be counting at the same rate then you bring up the point. Have the children look for examples of events that occur at uniform rates that could be used as counting guides (water drips, pulse, watch tick, metronome, or pendulum.) Let one student be the master counter for the class using one of these kinds of guides. He can say something like "now" each time an event occurs. Each timer can time the other member of his pair by counting along with the master counter.

Is the class champion the same as it was before when each timer counted the way that he chose? Conclude this activity with a class discussion of the problems of timing events as suggested by this activity (uniform counting of standard events).

Activity 2

Objective: Given some material that can flow from one container to another a student will be able to use the materials and containers to make a clock suitable for timing events.

Materials:
1 empty frozen juice can (large) per class
1 soft drink bottle per class
1 crayon per class
1 quart plastic container per class
1 clock (or watch) with a second hand per class
several sheets of newspaper per class

State that you will ask two students in turn to do a task for you. The task should be something that will take several minutes such as walking a round trip to some place in the building. Ask the children how they might determine which student takes the longest time to do the task. After a brief discussion of the ideas suggested by the students, construct a water clock in front of the class using a couple of student assistants.

A water timer can be made from a tin can with a hole in the bottom made by a thumb tack, together with a soft drink bottle. If the can is set on top of the soft drink bottle the water level in the bottle will rise about an inch a minute as water drains into it from the can. To operate the water timer one child should hold the can with a finger over the hole in the bottom while another child fills the can with water. Several sheets of newspaper on the desk should take care of spills and a quart plastic container half filled with water should be suitable for pouring.

The first student should now be asked to carry out the designated task. At the signal to begin, one of your assistants is to place the punctured can containing water over the soft drink bottle and allow the water to empty into the bottle. When the student returns from the task the timer is stopped by lifting the punctured can and covering the hole with a finger. A crayon mark is to be made on the side of the bottle at the upper level of the water.

The can is now to be refilled to the same level as before and a second student sent on the same designated task. The same procedures are to be followed and at the end both crayon marks are to be compared to find out which student did the task in the shortest time.

Repeat the timing procedure for several other tasks to give other students experience with the water timer.

Now let the same children calibrate the timer with a clock. One student can watch the hand on the clock and call out the minutes for another to mark with a crayon on the side of the bottle.

Let other children try their hand at calibrating the water clock and compare their marks with those made by others.

A number of questions are to be asked about the water timer in a discussion that follows the activity. Does the water always run out through the hole at the same rate? (No, it runs out faster when the can is full.) How do you know this? How can we find out? (The minute marks on the bottle are farther apart at first and get closer together as the can empties.)

Activity 3

Objectives: A student will be able to measure small time intervals in seconds without the aid of timing devices. A student will be able to match a pendulum's period of swing to a timing device by adjusting the length of the pendulum.

Materials:

- 1 small metal weight per class
- 1 two-foot length of string per class
- 1 clock with a second hand per class

Have one student assistant construct a pendulum from the string and weight. Now have another student assistant hold the pendulum string by loosely winding it around his finger. He is to allow the weight to swing freely and adjust the length of the string so that the weight makes about 10 complete round trips in 10 seconds. Someone in the class can call out the seconds while observing a clock to help him. When it is adjusted, let him use his "pendulum clock" to find the time interval between two events that take place in the classroom such as two claps of your hands. Try the same activity over again several times with other students who wish to try out their talents at adjusting the pendulum and using it as a clock.

Now have the students count in unison with the swinging pendulum, noting that there is a quiet period between each count. Ask: If we had longer names like "steamboat," "elephant," or chimpanzee," could we just about keep time with the "seconds" of the swings of the pendulum clock with their eyes closed to see if they can keep time with the pendulum clock. Ask them if the size of the swing of the string makes any difference. (Negligible) Ask them if the length of the string makes any difference and in what way. (Longer lengths take longer times for a complete swing.)

APPENDIX B.5

Experimental Units for Sixth Grade

Water

Adapted from materials published in

Kitchen Physics by Elementary Science Study of

Educational Services Incorporated, 1965

Teachers' Guide

Unit Title - Plain and Soapy Water

Grade Level - 6

Type Instruction - Small groups of students with large amounts of material.

Time Schedule
  Day 1 Activity 1 begin
  Day 2 Activity 1 end
  Day 3 Activity 2 begin
  Day 4 Activity 2 end
  Day 5 Activity 3
  Day 6, 7 Individual testing of students

Background

While examining the flow of liquids through various sized openings, the children will be introduced to experimental technique and error. They immediately begin making observations, making quantitative measurements, and taking data. They learn to represent their data graphically and begin to appreciate the usefulness of logically ordered arrangements.

Activity 1

Objectives: Given sample data from a time to empty experiment, a student will be able to identify any information not in its proper place in the data columns.

Given specific information about a time to empty experiment, a student will be able to predict generally how the information would change if one thing in the experimental conditions was changed slightly.

Grouping Size - 4 students per group

Materials:

1 plastic bottle with hole in bottom per group
5 bottle caps with various size holes per group
  (use only the 4 largest holes)
1 plastic quart container per group
1 half pint milk container per group
1 bucket of water per class
timing devices (capable of measuring seconds)
detergent
newspapers

Note: The day before starting this exercise make a survey of the watches that students wear to find out how many have second hands. If there will not be enough watches with second hands to go around bring in some electric clocks from home.

Provide each group with a plastic bottle with a hole in the bottom and a set of 4 caps with various size holes in them. Call the cap with the largest hole "Cap A," the one with the second largest hole "Cap B," and so forth. The plastic quart container will be a private sink for each group. Newspapers under the container will take care of minor spills. Have each group get a milk container full of water and fill the plastic bottle with this water. Remind the students to cover the hole in the bottom of the bottle with a finger. Have the children insert Cap A and time how long it takes for the bottle to empty into the quart container when the finger is released from the hole in the bottom of the bottle. Each student in the group is to get his own data for Cap A. Repeat the same experiment with each of the other size cap holes. Every group is to compute an average value for the time to empty through each size hole. The results of each group are to be recorded on the chalkboard so that comparisons between groups can be made. A permanent record of each group's data is also to be made for future reference. A class discussion centered on possible causes for variations in results should follow. Pose questions like:

"What was the average number of seconds for Cap B?...Cap D?"
"Which cap had the biggest range?"
"Which cap gave the most consistent results?...the least?"
"What size hole would take 100 seconds to empty the bottle? ...10 seconds?"
"How many seconds would it take for a cap smaller than A but larger than B?...For a cap smaller than C but bigger than D?"
"How many seconds for a cap bigger than A?...smaller than C?"
"Do you think soapy water would empty faster than plain water?"

On the second day of this activity repeat the entire activity using soapy water. Half a teaspoon of detergent per milk carton is sufficient. The results shouldn't be too different from those with plain water. In the discussion compare the results of the two experiments. Ask the children if there seems to be any significant difference.

Activity 2

Objectives: Given sample data from a column of falling water experiment, a student will be able to identify any information not in its proper place in the graphs of results.

Given specific information about a column of falling water experiment, a student will be able to predict generally how the information would change if one thing in the experimental conditions was changed slightly.

Grouping size - 4 students per group

Materials:

1 plastic bottle with hole in bottom per group
5 bottle caps with various size holes per group
1 plastic quart container per group
1 half pint mild container per group
1 bucket of water per class
newspapers
detergent
strips of colored paper, paste, large sheets of paper

Caution: Make sure that the materials have been thoroughly rinsed from the previous activity. Even a slight trace of detergent will create problems in this activity.

Using plain water and cap A have one person in each group raise and lower the bottle while it is draining into the plastic quart container. If the group listens carefully they will find a position where the noise level of the falling water hitting the water in the sink seems to change. The column of water breaks up into drops at a certain distance below the bottle cap hole. Have one of the group hold a strip of colored paper beside the column of falling water and tear it off so that its length is the same as that of the solid portion of the falling water column. The strip should be labeled A. Everyone in the group should take his turn and make his own strip "A". The activity should be repeated for each of the other caps.

Now have each student paste his strips on large sheet of paper and put his initials on the paper for identification purposes.

In the discussion of the experiment ask the students what they can tell about the beading. Were there any differences in length of the five unbroken columns? Select a variety of the children's paste-ups for display--some ordered and some quite random. These can be taped to the chalkboard or to the wall.

Cut a strip of construction paper somewhere in between the longest and shortest of the children's strips on display. Hold it up and tell the class that your strip came from an experiment similar to theirs. Ask if the children can tell you what the strip represents. (Length of unbroken water column). Now ask if by looking at the strip they can tell you which hole was used. "Can you tell me where on this chart I could place my strip? (Point to one of the unordered paste-ups on display.)

Now turn to an ordered arrangement of strips and ask the same question. Play the game again, using strips much longer or shorter than the strips made by the children. See if they can infer the size of hole associated with these strips. Ask them to try placing your strips on one of their ordered graphs.

Finally ask the class: "Can we change the lengths of the columns without changing the size of the holes?" Each of the answers suggested could be tested but the one that will be actually done will be to change the liquid by adding something to the water.

On the second day of this activity repeat the same experiment using soapy water. Half a teaspoon of detergent per milk container is sufficient. This time have all scientists make ordered graphs. Compare them to the graphs made the previous day.

Start a discussion about the breaking points of plain and soapy water columns. Try to word your questions in a way that makes the children look at their strips for the answers. Wind up the subject with an overall discussion of their experiences and results. "What do you think happened?" gives more likely responses than "What happened?" Urge the students to base their statements on their own experimental experiences—to justify as well as suggest reasons.

Some of the words and phrases that children use in explaining the results, though occasionally contradictory, are nicely descriptive.

"Water is stickier."
"Soap holds together better, so there is less left over to
hold to the bottle."
"Soap is thinner."
"It is more of a solid; there's more stuff in soap."
"Soapy water is heavier, so it sticks together better."
"Air pushes the column apart."
"Some drops fall faster than others and so break away from

the slower ones."
"If the hole is big, the force of air breaks it immediately."
"Water has more togetherness."

These actual statements of children are explanations for why bigger holes give longer columns and soapy water gives longer columns than plain water. Don't take sides in the discussion. Try to point out the fact that there may be more than one logical explanation for what happened and that additional evidence and experiments would be necessary in order to find out which explanation is really correct.

During the discussion period, the arguments presented and defended make some children think more critically about what they have done. They may wish to return to the materials and do the experiments over. Whether to prove a point or test a new idea, by all means let them try the experiments again.

Activity 3

Objectives: Given unmarked samples of plain water and water with a slight amount of detergent in it a student will be able to tell which is which with the aid of an eye dropper and a piece of wax paper.

Grouping Size - 4 students per group

Materials:

- 2 plastic medicine cups per group
- 2 eye droppers per group
- 2 half pint milk containers per group (one for plain water and the other for soapy water)
- 1 bucket of water per class
- newspapers
- wax paper, one piece per group

After the materials have been distributed have each group member see how many drops of water can be added to a level cup of water before it begins to spill. Ask them to use an eye dropper and count the number of drops they put in.

After everyone has had a chance to heap the water, ask them to predict what would happen if soapy water were used instead of plain water. To try this experiment have the students fill plastic cups with soapy water. The additional drops from the eye dropper are to be plain water. Everyone should have a chance to try heaping the drops as before. They should observe that soapy water does not heap up as high as plain water.

Now have the students predict what will happen if drops of soapy water and plain water are put on wax paper. After they have predicted the outcome have them try it. (Plain water will give higher drops than soapy water.) Remember that once an eye dropper has been contaminated with detergent it cannot be used to dispense plain water until it has been cleaned. It would be most convenient for each group to reserve one eye dropper for each kind of liquid to prevent contamination.

Complete the activity by a discussion of what the children think happened. In attempting to explain heaping, students generally formulate "theories" like the following:

"The heavier it is, the more it gets pushed down. Therefore soapy water must be heavier than plain water."

"The thicker it is, the less likely it is to run over the edge. Therefore, water is thicker than soapy water."

"Water holds together better than soapy water: its grabbier."

Perhaps the children can suggest some ways to check up on these theories.

If you think that this unit is leaving things up in the air by stopping now, you are correct. The material from which this unit has been adapted runs a minimum of two dozen lessons with many experiments to check out just about any theories that the children may have.

Note: Remember the contamination problem with the eye droppers and how to get around it.

Teachers' Guide

Unit Title - Plain and Soapy Water

Grade Level - 6

Type Instruction - Entire class of students working with limited amounts of material.

Time Schedule
Day 1 Activity 1 begin
Day 2 Activity 1 end
Day 3 Activity 2 begin
Day 4 Activity 2 end
Day 5 Activity 3
Day 6, 7 Individual testing of students

Background

While examining the flow of liquids through various sized openings, the children will be introduced to experimental technique and error. They immediately begin making observations, making quantitative measurements, and taking data. They learn to represent their data graphically and begin to appreciate the usefulness of logically ordered arrangements.

Activity 1

Objectives: Given sample data from a time to empty experiment, a student will be able to identify any information not in its proper place in the data columns.

Given specific information about a time to empty experiment, a student will be able to predict generally how the information would change if one thing in the experimental conditions was changed slightly.

Materials:

1 plastic bottle with hole in bottom
5 bottle caps with various size holes (use only the 4 largest holes)
1 plastic quart container
1 half pint milk container
1 bucket of water per class
timing device (capable of measuring seconds)
detergent
newspapers

Note: The day before starting this exercise make a survey of the watches that students wear to find out how many have second hands. If you do not think that there will be enough of them so that many small groups can help with the timing, then bring in some electric clocks from home that can be placed around the room.

Select four assistants from the class. Provide them with a plastic bottle with a hole in its bottom and a set of 4 caps with various size holes in them. Call the cap with the largest hole "Cap A," the one with the second largest hole "Cap B," and so forth. The plastic quart container will be a sink for the experiment. Newspapers under the container will take care of minor spills. Have one of the assistants get a milk container full of water and fill the plastic bottle with this water. Remind him to cover the hole in the bottom of the bottle with a finger. Have him insert Cap A and let the class time how long it takes for the bottle to empty into the quart container when the finger is released from the hole in the bottom of the bottle. Everyone of the four assistants is to do this and each of the four times to empty with Cap A is to be recorded by every student on a sheet of number paper. Repeat the same experiment with each of the other size cap holes. Each student is to keep his copy of the data for future reference. A class discussion centered on possible causes for variations in results should follow.

Pose questions like:

"What was the average number of seconds for Cap B?...Cap D?"

"Which cap had the biggest range?"

"Which cap gave the most consistent results?...the least?"

"What size hole would take 100 seconds to empty the bottle? 10 seconds?"

"How many seconds would it take for a cap smaller than A but larger than B?...For a cap smaller than C but bigger than D?"

"How many seconds for a cap bigger than A?...smaller than C?"

"Do you think soapy water would empty faster than plain water?"

On the second day of this activity repeat the entire activity using soapy water. Half a teaspoon of detergent per milk carton is sufficient. The results shouldn't be too different from those with plain water. In the discussion compare the results of the two experiments. Ask the children if there seems to be any significant difference.

Activity 2

Objectives: Given sample data from a column of falling water experiment, a student will be able to identify any information not in its proper place in the graphs of results.

Given specific information about a column of falling water experiment, a student will be able to predict generally how the information would change if one thing in the experimental conditions was changed slightly.

Materials:

1 plastic bottle with hole in bottom
5 bottle caps with various size holes
1 plastic quart container
1 half pint milk container
1 bucket of water
newspapers
detergent
strips of colored paper, paste, large sheets of paper

Caution: Make sure that the materials have been thoroughly rinsed from the previous activity. Even a slight trace of detergent will create problems in this activity.

As in the last activity, select a group of 4 assistants. Using plain water and Cap A, have one person in the group raise and lower the bottle while it is draining into the plastic quart container. If the class listens carefully they will find a position where the noise level of the falling water hitting the water in the sink seems to change. The column of water breaks up into drops at a certain distance below the bottle cap hole. Have one of the group hold a strip of colored paper beside the column of falling water and tear it off so that its length is the same as that of the solid portion of the falling water column. The strip should be labeled A. Everyone in the group should take his turn and make his own strip "A". The activity should be repeated for each of the other caps.

Now have each student assistant paste his strips on a large sheet of paper and put his initials on the paper for identification purposes. Have some do it in an orderly fashion and others in a disorderly fashion.

In the discussion of the experiment ask the students what they can tell about the beading. Were there any differences in length of the five unbroken columns? Tape the paste-ups to the chalkboard for a display.

Cut a strip of construction paper somewhere in between the longest and shortest of the children's strips on display. Hold it up and tell the class that your strip came from an experiment similar to theirs. Ask if the children can tell you what the strip represents. (Length of unbroken water column). Now ask if by looking at the strip they can tell you which hole was used. "Can you tell me where on this chart I could place my strip? (Point to one of the unordered paste-ups on display.)

Now turn to an ordered arrangement of strips and ask the same question. Play the game again, using strips much longer or shorter than the strips made by the children. See if they can infer the size strips on one of the ordered graphs.

Finally ask the class: "Can we change the lengths of the columns without changing the size of the holes?" Each of the answers suggested could be tested but the one that will be actually done will be to change the liquid by adding something to the water.

On the second day of this activity repeat the same experiment using soapy water. Half a teaspoon of detergent per milk container is sufficient. Hopefully, this time more of the children will arrange their strips in some order that nearly approximates a graph. Compare them to the graphs made the previous day.

Start a discussion about the beading points of plain and soapy water columns. Try to word your questions in a way that makes the children look at their strips for the answers. Wind up the subject with an overall discussion of their experiences and results. "What do you think happened?" gives more lively responses than "What happened?" Urge the students to base their statements on their own experimental experiences--to justify as well as suggest reasons.

Some of the words and phrases that children use in explaining the results, though occasionally contradictory, are nicely descriptive.

> "Water is grabbier."
> "Soap holds together better, so there is less left over to hold to the bottle."
> "Soap is thinner."
> "It is more of a solid; there's more stuff in soap."
> "Soapy water is heavier, so it sticks together better."
> "Air pushes the column apart."

"If the hole is big, the force of air breaks it
immediately."
"Water has more togetherness."

These actual statements of children are explanations for why bigger holes give longer columns and soapy water gives longer columns than plain water. Don't take sides in the discussion. Try to point out the fact that there may be more than one logical explanation for what happened and that additional evidence and experiments would be necessary in order to find out which explanation is really correct.

During the discussion period, the arguments presented and defended make some children think more critically about what they have done. They may wish to return to the materials and do the experiments over. Whether to prove a point or test a new idea, by all means let them try the experiments again.

Activity 3

Objective: Given unmarked samples of plain water and water with a slight amount of detergent in it a student will be able to tell which is which with the aid of an eye dropper and a piece of wax paper.

Materials:

2 plastic medicine cups per group
2 eye droppers per group
2 half pint milk containers per group
  (one for plain water and the other for soapy water)
1 bucket of water per class
newspapers
wax paper, one piece per group

As in the previous activities select a group of four assistants. After the materials have been distributed have each assistant see how many drops of water can be added to a level cup of water before it begins to spill. Ask them to use an eye dropper and count the number of drops they put in. Record each result on the chalkboard.

After every assistant has had a chance to heap the water, ask the class to predict what would happen if soapy water were used instead of plain water. To try this experiment have the assistants fill plastic cups with soapy water. The additional drops from the eye dropper are to be plain water. Every assistant should have a chance to try heaping the drops as before. They should observe that soapy water does not heap up as high as plain water.

Now have the class predict what will happen if drops of soapy water and plain water are put on wax paper. After they have predicted the outcome have them try it. (Plain water will give higher drops than soapy water.) Remember that once an eye dropper has been contaminated with detergent, it cannot be used to disperse plain water until it has been cleaned. It would be most convenient to reserve one eye dropper for each kind of liquid to prevent contamination. Allow members of the class to see the results for themselves by distributing small bits of wax paper around the room and having your assistants go around putting a drop of each kind of the bits of wax paper.

Complete the activity by a discussion of what the children think happened. In attempting to explain heaping, students generally formulate "theories" like the following:

"The heavier it is, the more it gets pushed down: therefore

soapy water must be heavier than plain water."
"The thicker it is, the less likely it is to run over the
edge. Therefore, water is thicker than soapy water."
"Water holds together better than soapy water: it's
grabbier."

Perhaps the children can suggest some ways to check up on these theories.

If you think that this unit is leaving things up in the air by stopping now, you are correct. The material from which this unit has been adapted runs a minimum of two dozen lessons with many experiments to check out just about any theories that the children may have.

Note: Remember the contamination problem with the eye droppers and how to get around it.

APPENDIX B.6

Experimental Units for Sixth Grade

Energy

Adapted from materials published in

Science A--Process Approach by American Association for the

Advancement of Science, 1967.

Teachers' Guide

Unit Title - Potential and Kinetic Energy

Type Instruction - Small groups of students working with large amounts of material.

Time Schedule
Day 1 Activity 1, part 1
Day 2 Activity 1, part 2
Day 3 Activity 1, part 3
Day 4 Activity 2 begin
Day 5 Activity 2 end
Day 6 Activity 3
Day 7 Activity 4
Day 8, 9 Individual testing of students

Background

In this unit the students are presented with a physical system whose properties depend on several variables. A cart rolls down an inclined plane, collides with a block, and pushes the block along for measurable distance. The distance the block moves could be influenced by the height of the incline, the length of the incline, the mass of the cart, the mass of the block, the area of contact between the block and the sliding surface, or the nature of the surface. The students are asked to identify these variables and to design controlled experiments to determine the ways in which the variables might be related.

The students investigate situations and events that are best described using the concept of energy. Since energy is an important abstraction in later science courses it is important for students to have a leisurely period of experimentation so that the abstraction will seem reasonable to them when they are told about it. This exercise then should be regarded primarily as an exercise in experimenting rather than an exercise on potential and kinetic energy.

Kinetic energy is defined as energy of motion. Potential energy is defined as energy which can become energy under appropriate circumstances.

Activity 1

Objectives: Given an object and a single pan balance a student will be able to determine the mass of the object to within a .2 gm in 30 seconds.

Given a flat rectangular object and a meter stick a student will be able to determine the length of the object to within a tenth of a centimeter within 20 seconds.

Given some graph paper and a table of data having six paired numbers (all positive integers) a student will be able to construct a broken-line graph of the data.

Grouping size - 4 students per group

Materials:

1 balance and set of standard metric masses per group
1 meter stick per group
1 work sheet #1 per student
1 sheet graph paper per student

The activity is designed to review certain skills that students may or may not have been exposed to previously. Distribute one balance to each group. Also distribute one previously selected object to each group. Have the groups determine the mass of the object to the nearest gram. Proper technique is to first check to see if the balance pointer is off zero when nothing is on the balance. If the pointer is off zero then the balance wheels will have to be adjusted to bring it back to zero. The balance wheels are under the pan. Next the object which is being measured is put on the pan. The quickest way to achieve balance is to:

1. Make sure that the slider and all weights are on zero.
2. Move the biggest weight to the largest number notch that will not tip the balance.
3. Leave the biggest weight in the notch determined in step #2 and #3 and do the same thing with the smallest weight.
4. Leave the two biggest weights in the notches determined in steps #2 and #3 and do the same thing with the smallest weight.
5. Now finish off the balancing by moving the slider. The total mass is determined by adding all the numbers whose notches are being used with the amount indicated by the slider.

The objects should be shifted between groups several times until you are sure everyone knows how to use a balance.

The next day distribute one meter stick to each group. Explain to them how to read the meter stick. The markings that are about the width of your thumb nail are centimeters. The little lines between them, about the thickness of your pencil lead, are tenths of centimeters. The students should be able to measure the length of objects to the nearest tenth of a centimeter. Give each group something to measure to the nearest tenth of a centimeter. Rotate the objects between groups until you are sure that the students can measure the sizes of objects to the nearest tenth of a centimeter.

On the last day of this activity have the class do the graphing problems on work sheet number 1. Invent or find in mathematics text books as many additional problems as you think are necessary for the students to graph until you are sure that the students can construct simple graphs from data tables.

Work Sheet #1
Construction Broken-line Graphs

1. Bob's committee kept a record of the temperature for one day. At the right we see their record in table form. Let us use the information in the table to picture their record on a broken-line graph. We wish to picture pairing of elements from two sets, the set of times and the set of temperature readings.

Time	Temperature
9	60
10	65
11	65
12	80
1	85
2	90
3	90

a. On a piece of graph paper place the title of the graph. Draw two rays or horizontal and vertical axes. How are the axes placed in relation to each other?

b. What name shall we give to each axis?

c. Decide upon a scale for the vertical axis. What is the greatest temperature to be represented? What temperature shall each unit length on the vertical axis represent?

d. Mark a dot on your paper to represent the fact that at 9 o'clock the temperature was 60 degrees. What does (9.60) mean?

e. What temperature is paired with 10 o'clock? Make a dot on your paper to represent (10.65). Notice that the dot for 65 must be halfway between the points for 60 and 70.

f. Mark dots on your paper to represent the rest of the information in the table.

g. To help see how the temperature changed during the day, connect the dots with pictures of line segments. From your graph, describe what happens to the temperature during the hours of 9 A. M. to 3 P. M.

2. Picture the information below with a broken-line graph. What trend to you observe?

Population of United States

Year	Numbers in millions
1930	123
1940	132
1950	151
1960	178

3. Use the table; picture the information with a broken-line graph.

Number of people working

Year	Numbers in millions
1900	29
1920	42
1940	53
1960	71

Activity 2

Objective: Given an experiment involving objects moving down an inclined plane a student will be able to design an experiment to determine how changes in one variable will influence the distance a block that is hit at the bottom of the inclined plane will move.

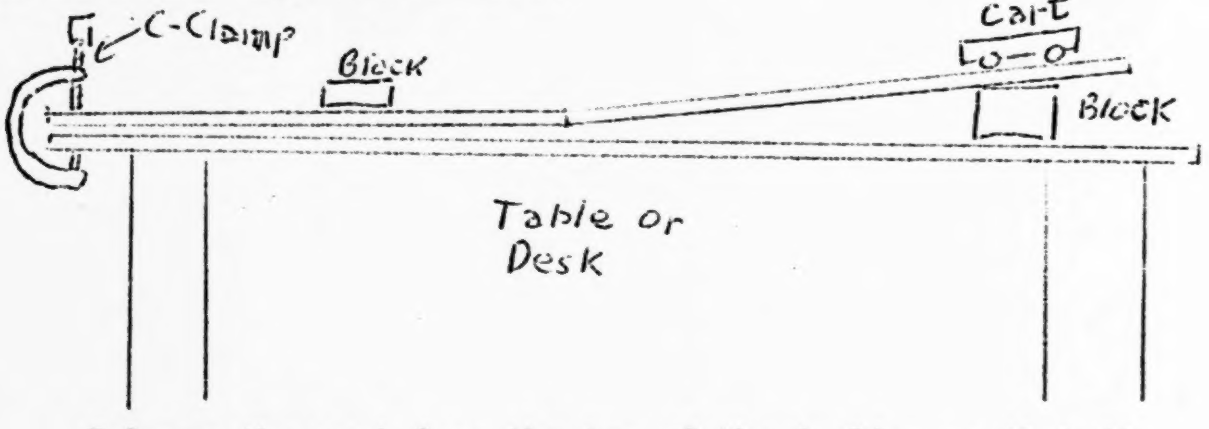
Given the results of an experiment involving two variables a student will be able to present the data in both tabular and graphical forms.

Grouping size - 4 students per group

Materials:

2 boards, 1 ft. x 3 ft.
1 four-wheeled cart per group
Assorted wood blocks, preferably smooth hardwood
1 masterstick per group
1 balance per group
1 roll masking tape per class
2 C-clamps per group
1 sheet graph paper per student

On the first day of this activity, in front of the class, set up an arrangement of an inclined plane, cart, and block similar to that shown in the drawing. The block should be located far enough away on the horizontal plane so that the cart is completely off the inclined plane before the collision between cart and block occurs.



Release the cart from the top of the incline so that it rolls down and collides with the block, pushing it along for some distance. The incline must not be so steep that the cart has difficulty rounding the corner at the bottom of the incline. Return the block to the starting position and repeat the demonstration. Ask the pupils to observe the event carefully and then describe what they see. Ask them to identify the variables which might have an influence on how far the block is pushed along the horizontal surface. Spend enough time discussing the problem so that a rather complete list of variables is made. The list should be placed on the chalkboard. Typical variables that will be suggested are:

Distance the block slides along the horizontal surface
Slope of the incline
Length of the incline
Height above the horizontal surface from which the cart is released
Mass of the cart
Mass of the block
Area of contact between the block and the sliding surface (vary sides or size of block)
Type of surface on the block, that is, the long way, crosswise, or on end
Friction in the wheels of the cart

Divide the class into groups of about four students each. Agree upon the variables that each group is to investigate, and make the following assignments: Design an experiment that controls variables. All but two are to be kept constant. One of the variables is to be the distance the block is moved. The other is to be varied systematically and its effect on the distance variable measured. Allow the groups to work independently on the experiment design. Have the groups describe for you or for the class a controlled experiment with provisions for recording data and making graphs. The groups will conduct these experiments the following day so be sure that they have the details well thought out. Do not design experiments around variables that students cannot measure, i.e. friction of wheels.

On the second day of this activity distribute the materials to the student groups so that each group can conduct its assigned investigations. The students need not all be doing something different, although this is possible. They should be given a minimum of assistance, and if they make incorrect measurements because of improper procedures, give them or their classmates ample time to discover the errors.

Some general suggestions that may be of help to all groups: A space equal to the length of the cart between the bottom of the inclined plane and the initial position of the block is needed so that the cart will be moving in a horizontal direction when it collides with the block. A line should be drawn on the board so that the block will always be returned to the same starting point. The block will not be pushed precisely the same distance by every collision; instead of measuring each distance and then averaging, it is more convenient to make a pencil mark to record the position each time, and then to measure the distance to a point near the center of all the marks. Occasionally the cart will make the block rotate as well as move forward. These trials should be rejected. The masses of the cart and block can be varied by attaching other blocks or standard masses securely with masking tape.

All groups should be told to arrange their data in both table and graph forms. They should also be told to study their data, to interpret it, and to be prepared to report their findings.

Activity 3

Objective: Given the graph of an experiment a student will be able to describe as a ratio how the vertical numbers vary as the horizontal numbers are varied by a small whole number ratio so long as the graph is one for either a direct or indirect relationship.

Given pictures of experiments similar to those performed in Activity #2, a student will be able to identify any situation in which the cart will hit the block and make it move.

Grouping Size - 4 students per group

Materials: None

In this activity the students will be asked to report the results of their investigations and to interpret their data. The interpretations that are made will depend upon the data. The groups might be asked the following questions if the answers are not given as part of their report and if the questions seem appropriate.

1. Describe what you did.
2. Present the measurements that were made (the data).
3. Does the distance of slide depend on the______?
   (Height of the cart, for example.)
4. If the______is increased, what happens to the distance of slide?
5. Do all the points on your graph lie along a straight line? If all the points were joined with straight line segments, what would be the shape of the curve?
6. If you made the______twice as great, would the distance of slide be twice as great? Half as great? Neither?
7. If you made the______four times as great, would the distance of slide be four times as great? Twice as great? One fourth as great? One half as great?
8. Does the distance of slide of the block depend on the velocity of the cart just before it hits?
9. Would the block have been pushed if the height from which the cart was released was zero? Must the height be different from zero to give a collision which slides the block along?
10. Can you suggest any explanation why the system behaved as it did? Why did things happen?

The students are also to be asked to examine their data to support answers to the questions. Conclusions which are not supported by the data should not be allowed, even though such conclusions might seem reasonable.

Activity 4

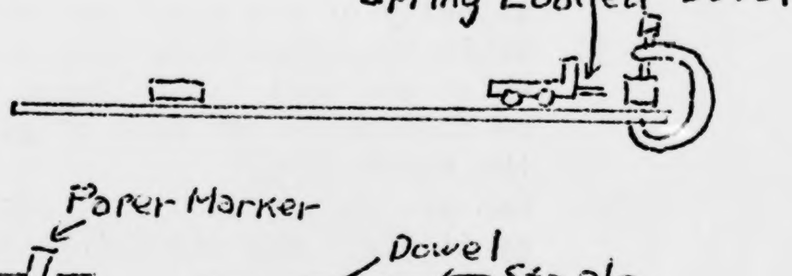
Objective: Given the graph of an experiment a student will be able to describe as a ratio how the vertical numbers vary as the horizontal numbers are varied by a small whole number ratio so long as the graph is one for a direct square relationship.

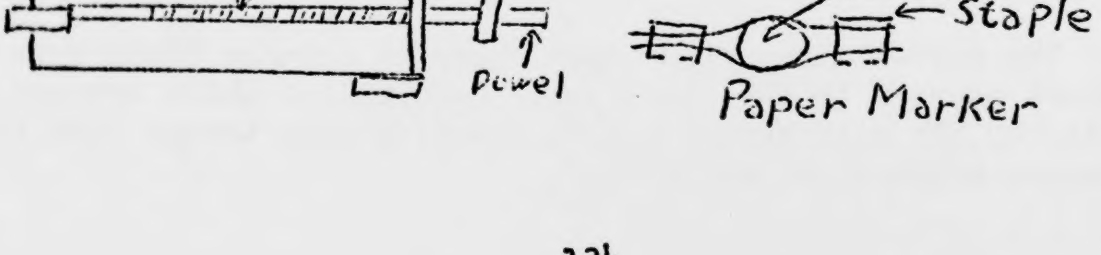
Given pictures of experiments similar to those performed in Activity #2 but involving compressed springs rather than inclined planes, a student will be able to identify any situation in which the cart will hit the block and make it move.

Grouping Size - 4 students per group

Materials:
1 board, 1 ft. x 3 ft. per class
1 four-wheeled cart with spring attached per group
Assorted wood blocks, preferably smooth hardwood
1 meterstick per group
1 roll masking tape per class
2 C-clamps per group
1 sheet graph paper per student

In this activity each group will do an experiment similar to that done previously. This time the energy for motion will come from a compressed spring mounted on the cart. A stapled paper marker mounted on the dowel attached to the spring will give an indication of the spring compression. The figures below show how the equipment is to be arranged. Each group will investigate the amount of energy stored in the spring by measuring the displacement of the block as before. The cart with spring attached is to be pulled back compressing the spring, released, and allowed to collide with the block. Tables and associated graphs of amount of block displacement vs. amount of spring compression (both measured in centimeters) are to be made. Questions like those for activity #3 should be asked at the end of the experiment but dealing with the amount of spring compression rather than the height.





Teachers' Guide

Unit title-Potential and Kinetic Energy

Type instruction-Entire class of students working with limited amounts of material.

Time Schedule

Day 1 Activity 1, part 1
Day 2 Activity 1, part 2
Day 3 Activity 1, part 3
Day 4 Activity 2 begin
Day 5 Activity 2 end
Day 6 Activity 2
Day 7 Activity 4
Day 8, 9 Individual testing of students

Background

In this unit the students are presented with a physical system whose properties depend on several variables. A cart rolls down an inclined plane, collides with a block, and pushes the block along for some measurable distance. The distance the block moves could be influenced by the height of the incline, the length of the incline, the mass of the cart, the mass of the clock, the area of contact between the block and the sliding surface, or the nature of the surface. The students are asked to identify these variables and to design controlled experiments to determine the ways in which the variables might be related.

The students investigate situations and events that are best described using the concept of energy. Since energy is an important abstraction in later science courses it is important for students to have a leisurely period of experimentation so that the abstraction will seem reasonable to them when they are told about it. This exercise then should be regarded primarily as an exercise in experimenting rather than an exercise on potential and kinetic energy.

Kinetic energy is defined as energy of motion. Potential energy is defined as energy which can become kinetic energy under appropriate circumstances.

Activity 1

Objectives:	Given an object and a single pan balance a student will be able to determine the mass of the object to within .2 gm in 30 seconds. Given a flat rectangular object and a meter stick a student will be able to determine the length of the object to within a tenth of a centimeter within 20 seconds. Given some graph paper and a table of data having six paired numbers (all positive integers) a student will be able to construct a broken-line graph of the data.
Materials:	1 balance per class 1 meter stick per class 1 work sheet #1 per student 1 sheet graph paper per student

This activity is designed to review certain skills that students may or may not have been exposed to previously. Demonstrate the use of a balance to the class. Supplement your demonstration by drawing a picture of the balance on the chalkboard. Select a volunteer and have him actually weigh an object, following out your verbal instructions. Do this several times with other volunteers until you are sure that everyone knows how to use the balance. Leave the balance accessible for the remainder of this unit and encourage students to use it when they have free moments.

Have the students determine the mass of the objects to the nearest gram. Proper technique is to first check to see if the balance pointer is off zero when nothing is on the balance. If the pointer is off zero then the balance wheels will have to be adjusted to bring it back to zero. The balance wheels are under the pan. Next the object which is being measured is put on the pan. The quickest way to achieve balance is to:

1. Make sure that the slider and all weights are on zero.
2. Move the biggest weight to the largest number notch that will not tip the balance.
3. Leave the biggest weight in the notch determined in step #2 and do the same thing with the second biggest weight.
4. Leave the two biggest weights in the notches determined in step #2 and #3 and do the same thing with the smallest weight.
5. Now finish off the balancing by moving the slider. The

total mass is determined by adding all the numbers whose notches are being used with the amount indicated by the slider.

The next day show the students how to read a meter stick. The markings that are about the width of your thumb nail are centimeters. The little lines between them, about the thickness of your pencil lead, are tenths of centimeters. The students should be able to measure the lengths of objects to the nearest tenth of a centimeter.

Use chalkboard demonstrations and volunteers as with the balance until you are sure that everyone knows how to use the meterstick. Leave the meter stick accessible for the remainder of this unit and encourage students to use it when they have free moments.

On the last day of this activity have the class do the graphing problems on work sheet #1. Invent or find in mathematics text books as many additional problems as you think are necessary for the students to graph until you are sure that the students can construct simple graphs from data tables.

Work Sheet #1
Construction Broken-Line Graphs

1. Bob's committee kept a record of the temperature for one day. At the right we see their record in table form. Let us use the information in the table to picture their record on a broken-line graph. We wish to picture pairing of elements from two sets, the set of times and the set of temperature readings.

Time	Temperature
9	60
10	65
11	65
12	80
1	85
2	90
3	90

   a. On a piece of graph paper place the title of the graph. Draw two rays or horizontal and vertical axes. How are the axes placed in relation to each other?

   b. What name shall we give to each axis?

   c. Decide upon a scale for the vertical axis. What is the greatest temperature to be represented. What temperature shall each unit length on the vertical axis represent?

   d. Mark a dot on your paper to represent the fact that at 9 o'clock the temperature was 60 degrees. What does (9.60) mean?

   e. What temperature is paired with 10 o'clock? Make a dot on your paper to represent (10.65). Notice that the dot for 65 must be halfway between the points for 60 and 70.

   f. Mark dots on your paper to represent the rest of the information in the table.

   g. To help see how the temperature changed during the day, connect the dots with pictures of line segments. From your graph, describe what happens to the temperature during the hours from 9 A. M. to 3 P. M.

2. Picture the information below with a broken-line graph. What trend to you observe?

Population of United States

Year	Numbers in millions
1930	123
1940	132
1950	151
1960	178

3. Use the table; picture the information with a broken line graph.

Number of People Working

Year	Numbers in Millions
1900	29
1920	42
1940	53
1960	71

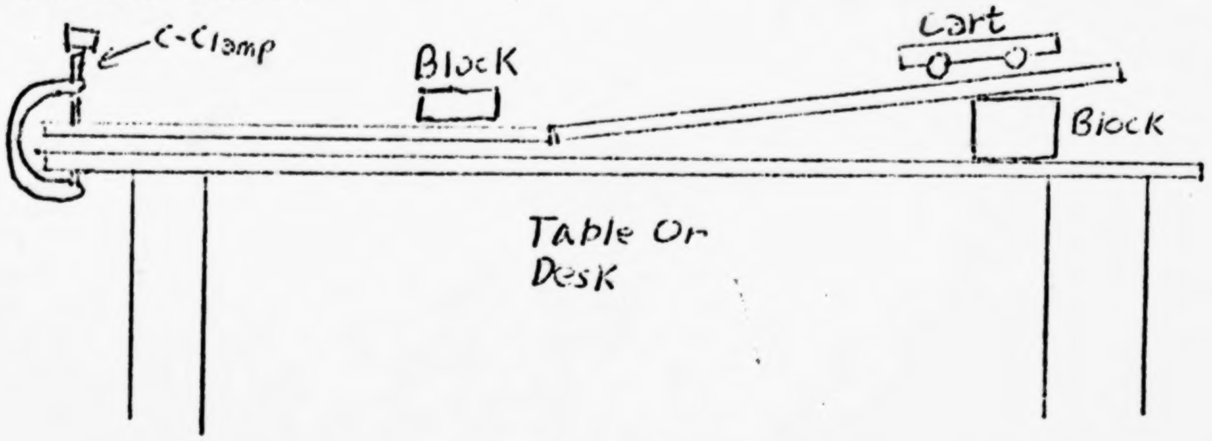
Activity 2

Objective: Given an experiment involving objects moving down an inclined plane a student will be able to design an experiment to determine how changes in one variable will influence the distance a block that is hit at the bottom of the inclined plane will move.

Given the results of an experiment involving two variables a student will be able to present the data in both tabular and graphical forms.

Materials:
- 2 boards, 1 ft. x 3 ft. per class
- 1 four-wheeled cart per class
- Assorted wood blocks, preferably smooth hardwood
- 1 meterstick per class
- 1 balance per class
- 1 roll masking tape per class
- 2 C-clamps per class
- 1 sheet graph paper per student

On the first day of this activity, in front of the class, set up an arrangement of an inclined plane, cart, and block similar to that shown in the drawing. The block should be located far enough away on the horizontal plane so that the cart is completely off the inclined plane before the collision between cart and block occurs.



Release the cart from the top of the incline so that it rolls down and collides with the block, pushing it along for some distance. The incline must not be so steep that the cart has difficulty rounding the corner at the bottom of the incline. Return the block to the starting position and repeat the demonstration. Ask the pupils to observe the event carefully and then describe what they see. Ask them to identify the variables which might have an influence on how far the block is pushed along the horizontal surface. Spend enough time discussing the problem so that a rather complete list of variables is made. The list should be placed on the chalkboard. Typical variables that will be suggested are:

- Distance the block slides along the horizontal surface
- Slope of the incline
- Length of the incline
- Height above the horizontal surface from which the cart is released
- Mass of the cart
- Mass of the block
- Area of contact between the block and the sliding surface (vary sides or size of block)
- Type of surface on the block and board
- Orientation of the block, that is, the long way, crosswise or on end
- Friction in the wheels of the cart

Divide the class into groups of about four students each. Agree upon the variables that each group is to investigate and make the following assignment: Design an experiment that controls variables. All but two are to be kept constant. One of the variables is to be the distance the block is moved. The other is to be varied systematically and its effect on the distance variable measured. Allow the groups to work independently on the experiment design. Have the groups describe for you or for the class a controlled experiment with provisions for recording data and making graphs. The groups will conduct these experiments the following day so be sure that they have the details well thought out. Do not design experiments around variables that students cannot measure i. e. friction of wheels.

On the second day of this activity allow each group to conduct its assigned investigation. The students need not all be doing something different, although this is possible. They should be given a minimum of assistance, and if they make incorrect measurements because of improper procedures, give them or their classmates ample time to discover the errors. Some investigations can be done as demonstrations in front of the class and some during free time. Use your own judgement on how best to give each group a chance to try out its investigation.

Some general suggestions that may be of help to all groups: A space equal to the length of the cart between the bottom of the inclined plane and the initial position of the block is needed so that the cart will be moving in a horizontal direction when it collides with the block. A line should be drawn on the board so that the block will always be returned to the same starting point. The block will not be pushed precisely the same distance by every collision; instead of measuring each distance and then averaging, it is more convenient to make a pencil mark to record the position each time, and then to measure the distance to a point near the center of all the marks. Occasionally the cart will make the block rotate as well as move forward. These trials should be rejected. The masses of the cart and block can be varied by attaching other blocks or standard masses securely with masking tape.

All groups should be told to arrange their data in both table and graph forms. They should also be told to study their data, to interpret it, and to be prepared to report their findings.

Activity 3

Objective: Given the graph of an experiment a student will be able to describe as a ratio how the vertical numbers vary as the horizontal numbers are varied by a small whole number ratio so long as the graph is one for either a direct or indirect relationship.

Given pictures of experiments similar to those performed in Activity #2, a student will be able to identify any situation in which the cart will hit the block and make it move.

Materials: None

In this activity the students will be asked to report the results of their investigations and to interpret their data. The interpretations that are made will depend upon the data. The groups might be asked the following questions if the questions seem appropriate.

1. Describe what you did.
2. Present the measurements that were made (the data).
3. Does the distance of slide depend on the _____?
4. If the ____ is increased, what happens to the distance of slide? Does it increase or decrease?
5. Do all the points on your graph lie along a straight line? If all the points were joined with straight line segments, what would be the shape of the curve?
6. If you made the ____ twice as great, would the distance of slide be twice as great? Half as great? Neither?
7. If you made the ____ four times as great, would the distance of slide be four times as great? Twice as great? One fourth as great? One half as great?
8. Does the distance of slide of the block depend on the velocity of the cart just before it hits?
9. Would the block have been pushed if the height from which the cart was released was zero? Must the height be different from zero to give a collision which slides the block along?
10. Can you suggest any explanation why the system behaved as it did? Why did things happen?

The students are also to be asked to examine their data to support answers to the questions. Conclusions which are not supported by the data should not be allowed, even though such conclusions might seem reasonable.

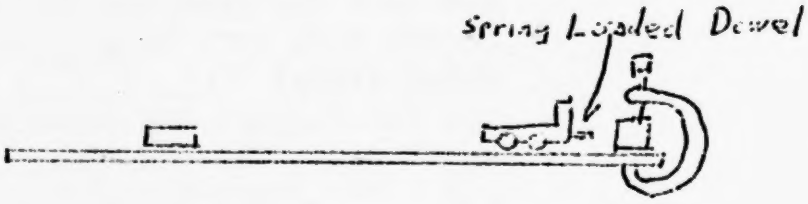
Activity 4

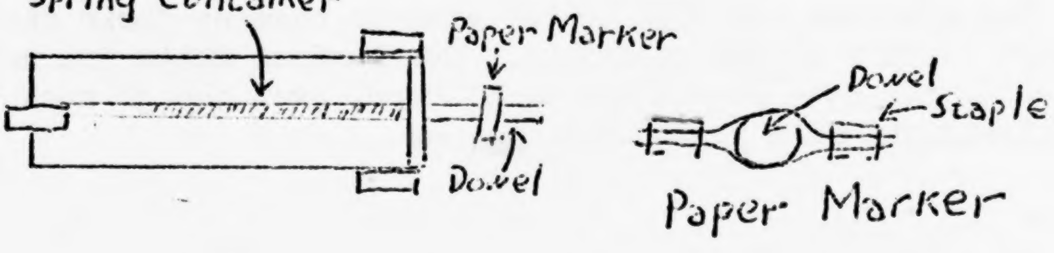
Objective: Given the graph of an experiment a student will be able to describe as a ratio how the vertical numbers vary as the horizontal numbers are varied by a small whole number ratio so long as the graph is one for a direct square relationship.

Given pictures of experiments similar to those performed in Activity #2 but involving compressed springs rather than inclined planes, a student will be able to identify any situation in which the cart will hit the block and make it move.

Materials:
- 1 board 1 ft. x 3 ft. per class
- 1 four-wheeled cart with spring attached per class
- Assorted wood blocks, preferably smooth hardwood
- 1 meterstick per class
- 1 roll masking tape per class
- 2 C-clamps per class
- 1 sheet graph paper per student

In this activity you will demonstrate, using student assistants, an experiment similar to that done previously. This time the energy for motion will come from a compressed spring mounted on the cart. A stapled paper marked mounted on the dowel attached to the spring will give an indication of the spring compression. The figures below show how the equipment is to be arranged. The purpose of the experiment is to investigate the amount of energy stored in the spring by measuring the displacement of the block as before. The cart with spring attached is to be pulled back compressing the spring, released, and allowed to collide with the block. Tables and associated graphs of amount of block displacement vs. amount of spring compression (both measured in centimeters) are to be made by every student. Questions like those for activity #3 should be asked at the end of the experiment but dealing with the amount of spring compression rather than the height.





APPENDIX C

Evaluative Criteria

C.1 Seeds--First Grade
C.2 Classification--First Grade
C.3 Temperature--Third Grade
C.4 Time--Third Grade
C.5 Water--Sixth Grade
C.6 Energy--Sixth Grade

Evaluation--Seed Unit Grade 1

1. Show subject a lima bean seed. "Here is a seed. Where do you think the root comes out?"

   ANS. Anywhere on the edge having the "eye" (2 points).

2. Show subject an assortment of 5 lima bean seeds 2 of which have been soaked for a day. "Which ones do you think have started to grow?"

   ANS. Full credit if exactly right (2 points). Partial credit if all not picked or if improper ones included (1 point).

3. Show subject a germinating lima bean seed. "You know that when a seed grows part of the seed remains below the ground and part of the seed goes above the ground. Show me the part that you think will be above the ground."

   ANS. Non-root parts (1 point).
   "Show me the part that you think will be in the ground."
   ANS. Root (lower portions) (1 point).

4. Continuing with the same germinating lima bean seed used in question 3 point at the root. "What do you think this is called?"

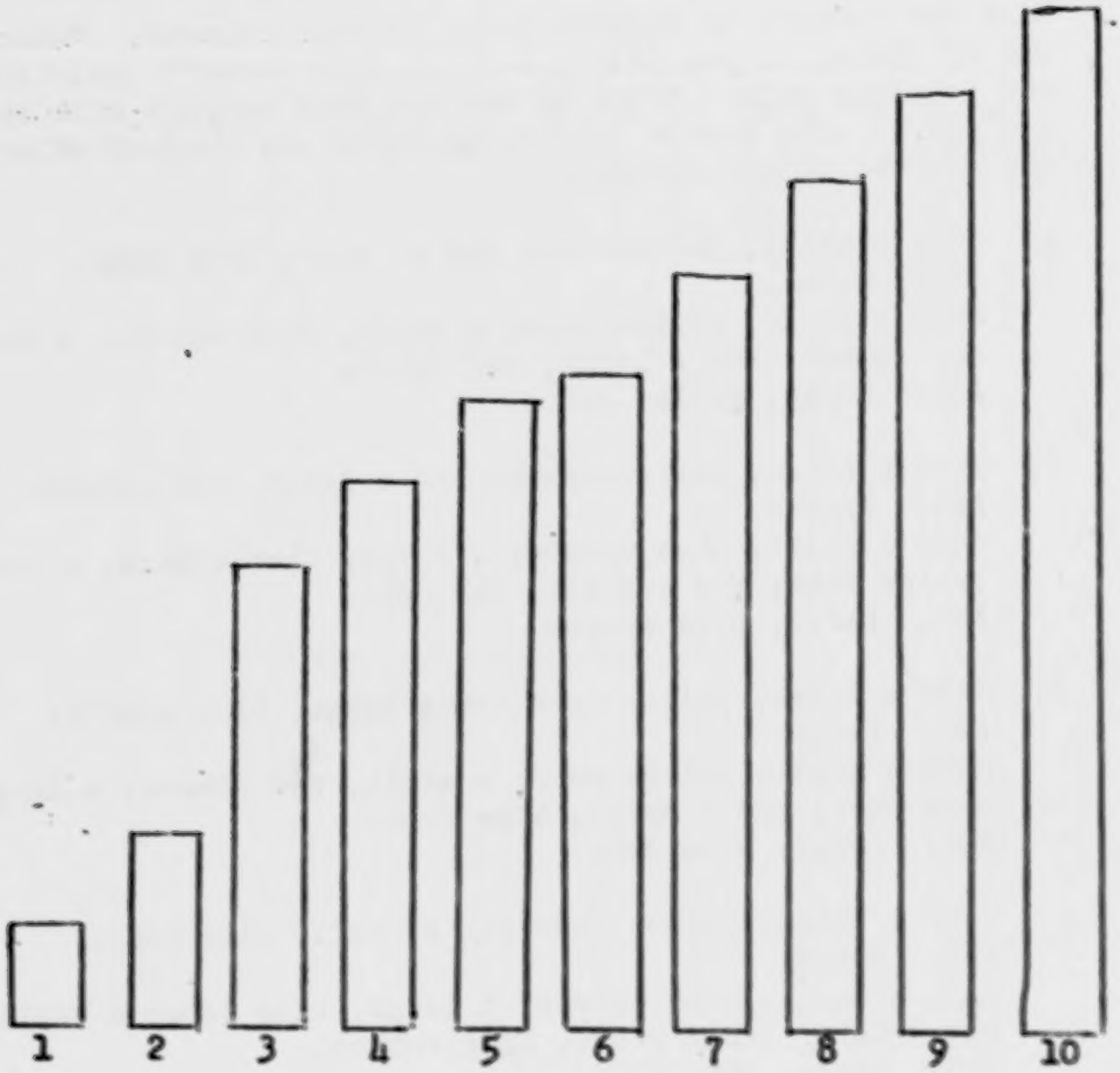
   ANS. Root (2 points).

5. Show subject a sample growth graph. "Remember in class you measured the height of your plant with pieces of colored paper. This is a picture of how my plant grew. See it grew a little bit the first day, then it grew bigger and bigger (pointing to the strips). Each strip of paper is the height of my plant on different days. What day do you think this plant grew the most?"

   ANS. Three (1 point)
   "What day do you think this plant grew the smallest amount?"
   ANS. Six (1 point).

Evaluation--Seed Unit Grade 1

Graph for Question #5



Evaluation--Classification Unit Grade 1

For each question the subject is first shown a pair of objects and is asked a question about them. "In what ways do you think that these are the same?" Give 1 point if the subject responds correctly.

Next the subject is shown a group of four objects. "Which one of these, do you think, belongs with those?" pointing at the previous pair. "Pick up the one that belongs with those and put it with them." Give 1 point if the subject selects the correct object to move.

1. Show a small, yellow cube and a large, blue cube.
   ANS. Cubes.
   Show a large, yellow cube; a small, blue sphere; a small, red sphere; and a large, red sphere.
   ANS. Large, yellow cube.

2. Show a large, yellow sphere and a large, red sphere.
   ANS. Sphere.
   Show a small, blue sphere; a large, blue sphere; a large, yellow cube; and a small, red cube.
   ANS. Large, blue sphere.

3. Show a large, yellow cube and a large, blue sphere.
   ANS. Large.
   Show a small, yellow cube; a small, red sphere; a large blue cube; and a small, blue cube.
   ANS. Large, blue cube.

4. Show a large, yellow cube and a small, blue cube.
   ANS. Cubes.
   Show a large, blue sphere; a large, blue cube; a small, red sphere; and a small, blue sphere.
   ANS. Large, blue cube.

5. Show a large, yellow sphere and a small, yellow cube.
   ANS. Yellow.
   Show a large, yellow cube; a small, blue sphere; a large red sphere; and a large, blue cube.
   ANS. Large, yellow cube.

Cubes can be called squares or boxes.
Spheres can be called circles or balls.
Accept answers that indicate that the subject knows the answer to the questions but is not quite using the correct word.

Evaluation--Thermometer Unit Grade 3

1. Show subject a thermometer which is in warm water. "Suppose I take this thermometer out of the warm water. Do you think that the temperature reading of the thermometer will go up or down?"
   ANS. Down (2 points)

2. Show subject a thermometer in the same water as above. "What is the temperature reading on this thermometer?"
   ANS. Give two points if answer is within one degree of being correct and one point if it is within 2 degrees of being correct.

3. Show subject a cup of water with a thermometer in it. Let him read the thermometer. Now take out the thermometer and pour about half the water into an empty cup while asking the question, "What do you think would be a reasonable temperature of this water that I am pouring into the empty cup?"
   ANS. Give two points if subject gives an answer within one degree of the original temperature and one point if the answer is within two degrees.

4. Show subject two cups with equal amounts of hot and cold water in them. Let him see thermometer readings of the two kinds of water. "In this cup I have warm water at ___° (read it and writeit down for him to see). In this other cup I have the same amount of cold water at ___° (read it and write it down as before). Suppose I pour the cold water in the warm and mix it up. What will be the temperature reading if both of these samples are completely mixed together? I will do any arithmetic for you that you want me to do to help you find the answer."

   ANS. Full credit (2 points) if the answer is within two degrees of being exactly midway between the two original temperatures. Partial credit (1 point) if the answer is within five degrees of being exactly midway between the two original temperatures.

5. Show subject two cups with obviously unequal amounts of hot and cold water in them. Have about twice as much cold water as warm water. Let him see thermometer readings of the two kinds of water. The temperatures should be the same as in the last question. "Here is a cup with twice as much cold water as before but at the same temperature. The other cup has just as much warm water as before at the same temperature. Now suppose I pour this cup of cold

water in the warm. Where will the temperature end up?"

ANS. Give two points for an answer within two degrees of one third of the way between the cold temperature and the warm temperature. Give one point for an answer between the low temperature and a midway temperature between the cold and warm temperatures.

Evaluation--Time Unit Grade 3

1. Give subject a container of salt, a plastic graduated cylinder, a clock with a second hand, and a frozen juice can (punctured). "You can make a salt clock just like the water clock that you made in class. Show me where to mark this clock for one minute."
   ANS. Follows procedure correctly and marks the clock in the right location. (2 points)

2. Show subject pictures of four calibrated water clocks. "Which of these is closest to being marked correctly?"
   ANS. C is the correct one (2 points).

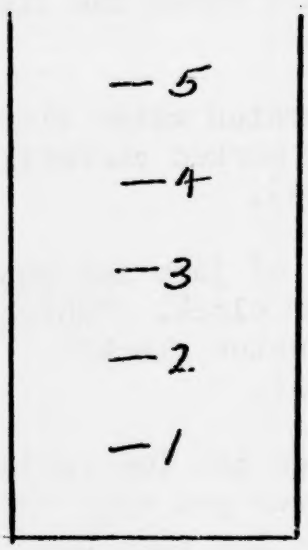
3. Show student pictures of four types of jars and bottles that could be used in making a water clock. "Which of these would make the most accurate water clock?"
   ANS. A is the correct one (2 points).

4. Without the aid of any timing devices ask the subject to "Clap your hands, count or do whatever you want but tell me when 10 seconds have gone by from the time that I say go. Ready? Go."
   ANS. Results within 1 second of being correct (2 points). Results within 2 seconds of being correct (1 point).

5. Have a pendulum set originally at about $1\frac{1}{2}$ feet of length. "Adjust this pendulum to swing in seconds."
   ANS. Pay attention to only the first move to adjust the pendulum. Give full credit (2 points) if subject adjusts the length immediately to about one foot. Give partial credit (1 point) if he makes a move to shorten the length.

Evaluation--Time Unit **Grade 3**

Question 2



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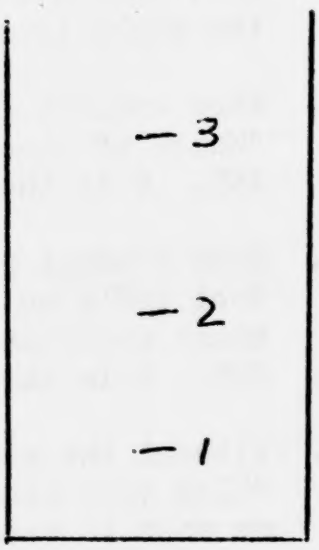

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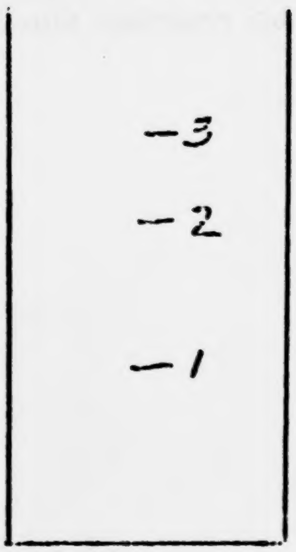

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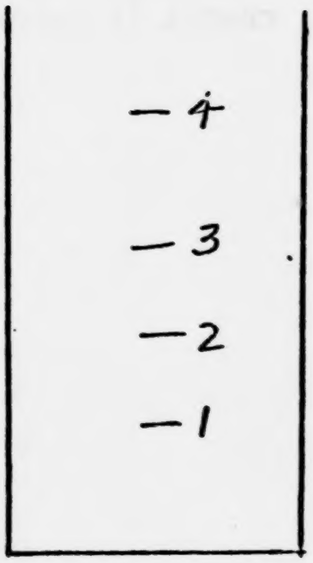
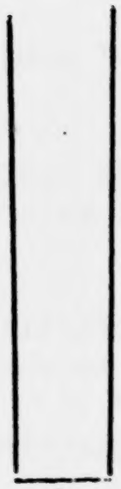


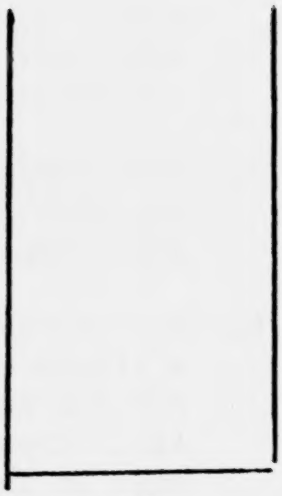
D

Evaluation--Time Unit Grade 3

Question 3



A



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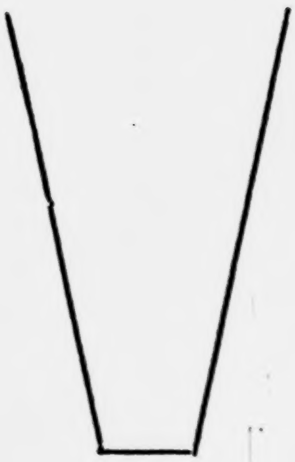

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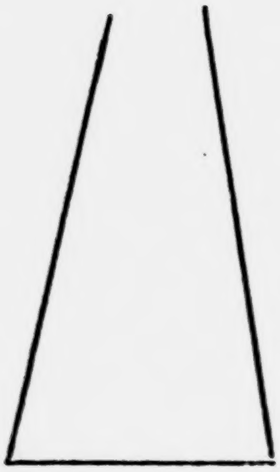


D

Evaluation--Water Unit   Grade 6

1. Given two containers, one containing plain water and the other soapy water with no foam, two eyedroppers and some wax paper, ask "Show me how you can tell which of these is plain water."
   ANS. Give full credit (2 points) if subject demonstrates that plain water gives heaping drops.

2. Show subject some sample unordered data from a time to empty experiment. "How would these times vary if the bottle was held higher? Lower?"
   ANS. Give full credit (2 points) if subject says no difference each time.

3. Show subject the same data as in the last question. "Which cap will give the longest column of water?"
   ANS. Cap W (2 points)

4. Show subject a bottle held over a plastic container with a little water in it. "From where to where do you measure for the column experiment? Point."
   ANS. From the water level in the plastic container to the hole in the red cap. (2 points).

5. Show subject a drop of alcohol on wax paper. "Will this material have a longer, shorter, or about the same size column as plain water?"
   ANS. Longer (2 points).

Evaluation--Water Unit Grade 6

Questions 2 and 3

Cap	Time to Empty (Seconds)
V	63
W	30
X	400
Y	42
Z	97

Evaluation--Energy Unit Grade 6

1. Show subject the dittoed sheet depicting situations. "Show me two situations in which the block absolutely can not move. An arrow indicates motion."
   ANS. B and G are correct. Give 2 points if the response is absolutely correct. Give 1 point if at least one correct response is given but no more than than two incorrect responses are also made.

2. Show subject picture (k) on the dittoed sheet. "If the pendulum is let go and hits the block, from where to where do we measure in order to find out how far the block moved?"
   ANS. The beginning and ending positions of the block (2 points).

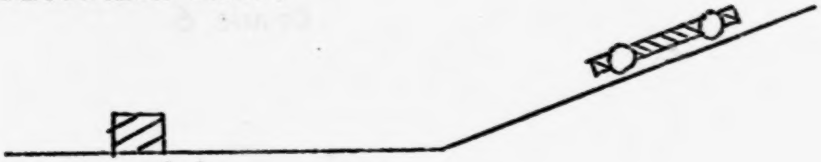
3. Show subject the straight line graph. "Each point on a line graph has two numbers. One reads down and one reads across." Use the graph to show what you mean. "Now suppose we take this point where the first number is 2. If we now multiply this number by 4 so we move along the line graph to this point (pointing) where the first number is now 8, how has the number we read in the down direction changed?"
   "Would the vertical number be four times as great? Twice as great? One fourth as great? One half as great?"
   ANS. Four times as great (2 points).

4. Give subject a balance. "Here is a 50¢ piece. Weigh it. The scale is already calibrated."
   ANS. After 30 seconds look at the settings made on the balance. If they are within 0.2 gm. of their being correct give 2 points. If they are within 0.5 gm. of being correct give 1 point.

5. Show subject picture (a) on the dittoed sheet. "What can you do to this set-up to make the block move a longer distance?
   ANS. Any of the following:
   Push cart.
   Put weight on cart.
   Make a steeper incline. (2 points)

Evaluation--Energy Unit
Situation Sheet

Grade 6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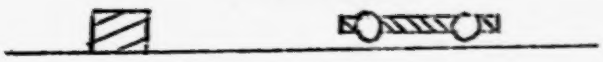
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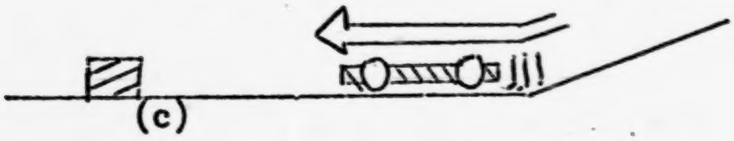
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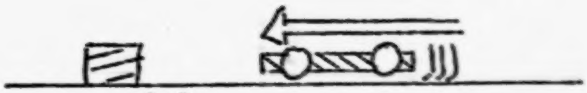
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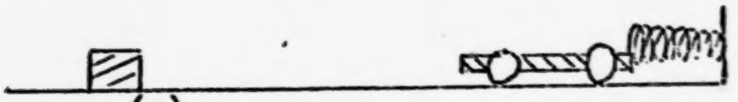
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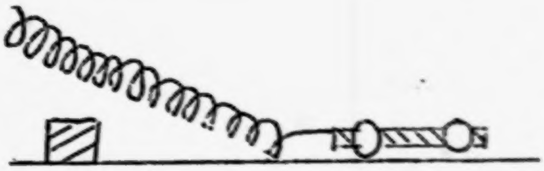
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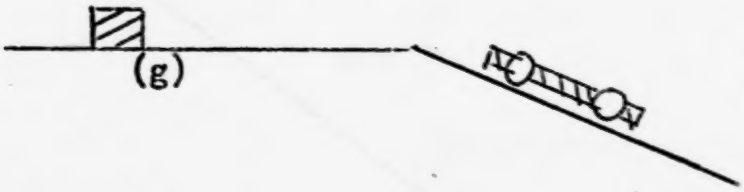
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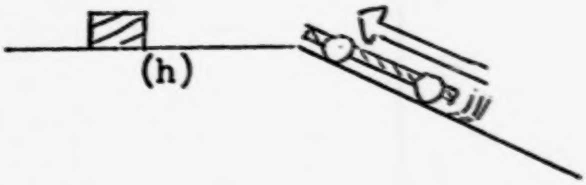
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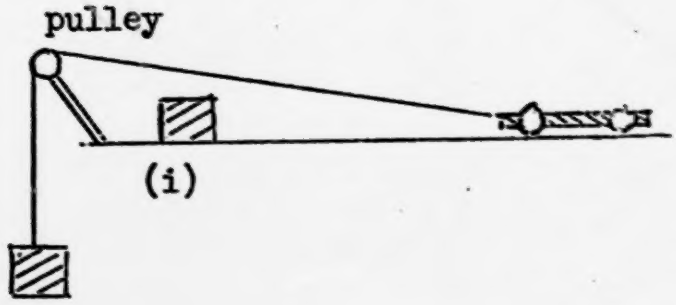

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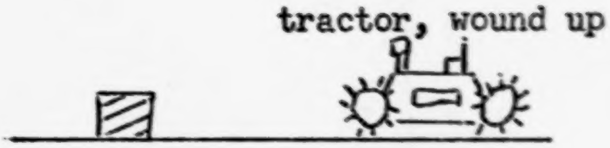
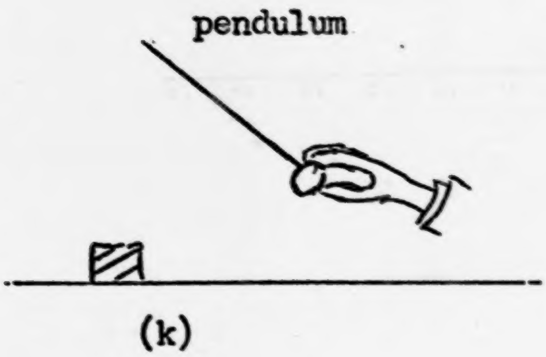
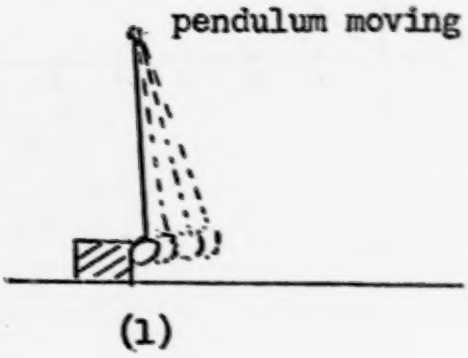

tractor, wound up
(j)

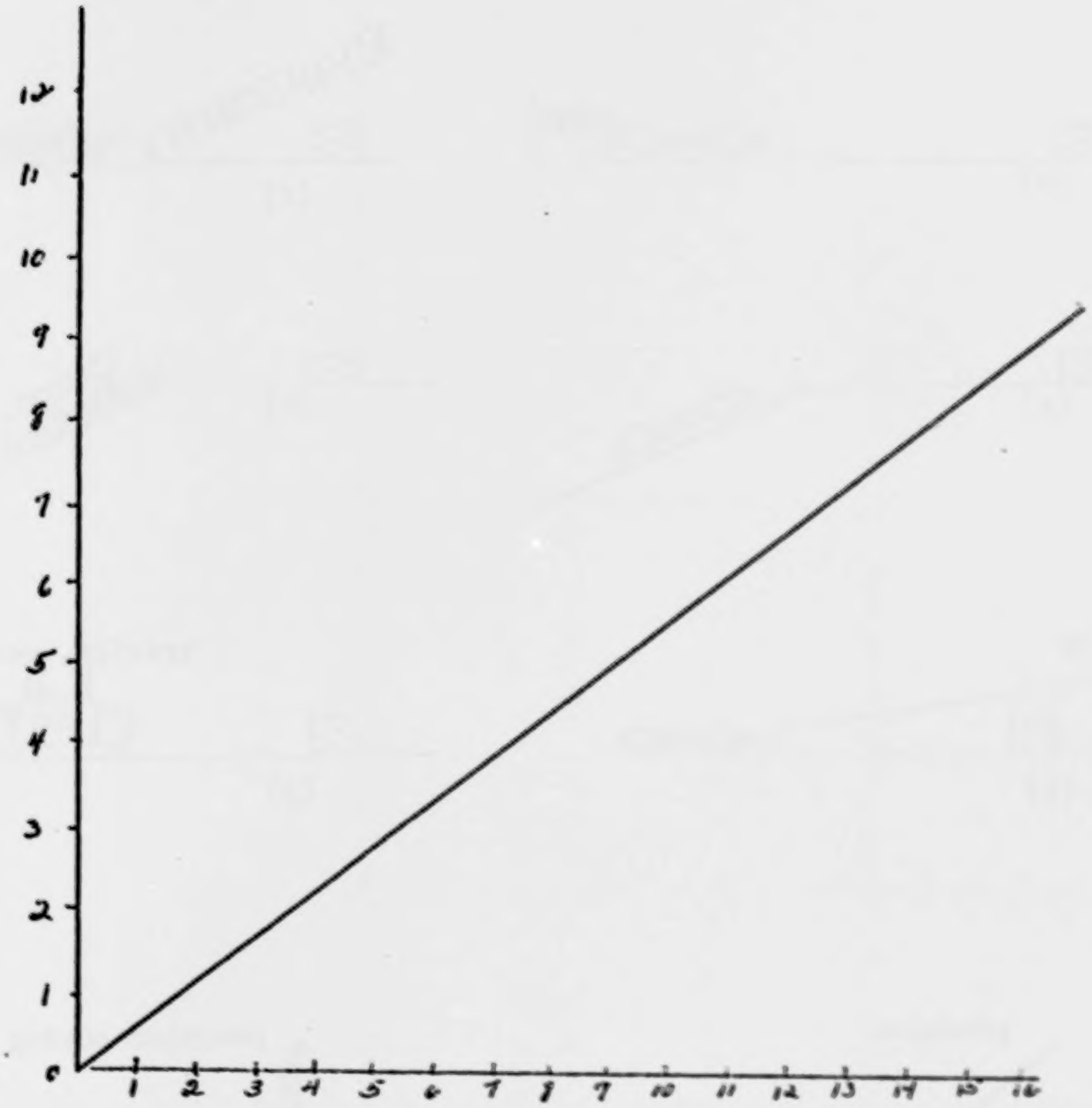


(k)


pendulum moving
(l)

Energy Unit Grade 6

Question 3



APPENDIX D

Questionnaires

D.1 Unit Questionnaire

D.2 Final Questionnaire

Teacher Name________________
(Will be cut off eventually to
protect identities)
Unit Title________________

General Information on Each Unit

1. Indicate your time involvement (in minutes) for this unit. Do not include any time in the initial training session.

	Preparation	Teaching	Clean-up
Activity 1			
Activity 2			
Activity 3			
Activity 4			

2. In your opinion would a student text improve this unit?
__________(Yes or No)

3. If you did any classroom demonstrations in the course of this unit, indicate how many you did and the number of repetitions of these demonstrations.

	Number of different demonstrations	Number of repetitions of each demonstration			
		1st	2nd	3rd	4th
Activity 1					
Activity 2					
Activity 3					
Activity 4					

If this is your second unit of the experiment answer the following questions:

4. What is your reaction to the materials that you have used in the course of this experiment?_________(Favorable or Unfavorable)

5. What is your reaction to the teaching methods used in the course of this experiment?______(Favorable or Unfavorable)

6. Comments.

Teacher Name____________________

Final Information Sheet

This information will be used to provide a background description of the teachers in our community as related to science.

1. For you, as an individual, was in-service training necessary to teach effectively the first unit that you taught?

____
Necessary or Not Necessary

Was it necessary to teach effectively the second unit?

2. How do you like science in comparison to other subject that you teach? Check one.

____Prefer it to other subjects.
____About the same as other subjects.
____Prefer other subjects to science.

3. How many semester hours of college credit in science courses do you have? Do not include courses in how to teach science.

______Semester hours

4. During an activity type science lesson, how do you generally maintain control over the activity. Check one.

_____All groups do each part of the activity simultaneously on specific direction from you.
_____All groups proceed at different rates through the activity getting help and guidance separately from you.

5. Comments.

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